# INTEGRATED MANAGEMENT OF THE LONE STAR TICK, *AMBLYOMMA AMERICANUM* (L.), THROUGH HABITAT MODIFICATION AND WHITE-TAILED DEER, *ODOCOILEUS VIRGINANUS* BODDAERT, MANIPULATION

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# CHAPTER I

## INTRODUCTION

Tick feeding on livestock and wildlife causes direct damages such as blood-loss and anemia. However, indirect damages resulting from tick feeding are possibly more important than direct damages. The feeding lesion is highly susceptible to secondary bacterial infections resulting in pustular, necrotic wounds which may ultimately debilitate, deform, and/or cause the death of the host animal. Disease transmission is another important indirect damage resulting from tick feeding. Landmark works in veterinary pathology and acarology resulted from the tick's ability to vector disease. As early as the 1890's, workers with the United States Department of Agriculture (U.S.D.A.) had established and proved for the first time that ticks were capable of vectoring disease to livestock. Theobald Smith and F.L. Kilbourne (1893) reported that the pathogen of Texas cattle fever (*Babesia bigemina*) was vectored by the Texas cattle fever tick [*Boophilus annulatus* (Say)]. Other indirect damages to livestock attributable to tick feeding include weight losses or poor efficiency in weight gains resulting from irritation and "tick worry", due to less time spent grazing by the host.

The economy of any agricultural region in the United States is significantly influenced by the level or degree to which arthropod pests of a particular commodity occur. The livestock industry, particularly the pastured or range-grazing cattle operation, is highly susceptible to devastating economic damage by arthropod pests. There were an estimated 84.5 million head of beef cattle, worth ca. $34.3 billion, grazing pastures or rangelands in the United States in 1982. The ticks (Order:Acarina) are among the most important organisms affecting the livestock producers ability to achieve a profit. Previous estimates of economic damages inflicted by all species of ticks on the pasture/range grazing cattle producers annual income were in excess of $550 million (U.S.D.A. 1976).

The economic damage associated with ticks are not, however, restricted to domestic livestock. Development of recreational areas are often deterred by the abundance of these pestiferous, disease- vectoring arthropods (Hair and Howell, 1970). The health and aesthetic qualities of wildlife are often affected by arthropod attack. In the United States there have been nine species of ticks reportedly found infesting white-tailed deer, _Odocoileus virginanus_ Boddaert. Studies of fawn mortality resulting from lone star tick infestations on white-tailed deer in Oklahoma, estimate annual losses as high as 50% (Bolte et al., 1970).

The livestock producer of today has become increasingly dependent on the use of pesticides as a primary, if not only, means of combating arthropod pests on many commodities. Limited success has been achieved in attempts to control or manage tick populations chemically in pasture or rangeland situations (Meyer et al., 1982). There are numerous commercially available, U.S.D.A. suggested acaricides available for tick control. However, most applications of these compounds call for whole body spraying or dipping of the animal repeated at seven to ten day intervals to effectively disrupt the ticks life cycle.

A continuous treatment regime to control lone star ticks on grazing cattle is required due to a rapid reinfestation of the pasture or rangeland with "non-treated" ticks. This reinfestation of the area is due to tick-infested wildlife occupying or frequenting the area and "reseeding" the perimeters, as is the case with the white-tailed deer in the Ozark region of eastern Oklahoma. This cycle of treatment-reinfestation-retreatment presents the livestock producer with a dilemma and evidence that pesticides are not the sole answer.

The continuous long-term use of chemical acaricides are potentially damaging to the ecosystem as well as possibly perpetuating resistant strains of ticks in many areas. Acaricidal applications to deer and other alternate hosts, to prevent reinfestation of grazing areas, is impractical.

To achieve a reasonably efficient, yet environmentally safe approach to controlling ticks, an integration of all available cultural, biological and chemical technologies must be implemented.

The use of Integrated Pest Management (I.P.M.) systems in livestock production has advanced in recent years, particularly in the management of ticks through habitat alteration (Meyer et al., 1982), host animal resistance (Byford, 1984), and continuous-release acaricidal application systems (i.e., ear tags) (Gladney, 1976). Available information on the lone star tick's basic biology, host interactions and economic thresholds has made it a likely species on which to develop such an integrated management approach.

The development of an effective I.P.M. program for the lone star tick must focus on three primary objectives: a) it must be environmentally safe; b) the program must focus on long-term population management, rather than short-term eradication within a specific area; and c) economic inputs must be practical and recoverable within reasonable time. This coordination of multi-disciplinary strategies and techniques into a workable tool for managing lone star ticks in pastures or rangeland areas would improve the quality of production and protect the natural environment simultaneously.

The white-tailed deer's preferred habitat type for foraging and bedding has been reported to be ecotone or "edge" areas between woodlots and meadows (Severinghaus & Cheatum, 1956). These ecotone areas provide dense understory of forbes and woody species which constitute the deer's primary diet. These areas are environmentally and ecologically conducive to lone star tick occurrence and survival due to the vegetative component and frequency of host presence.

This dissertation reports on a primary aspect of integrated management of the lone star tick: the manipulation of white-tailed deer through the modification of existing rangeland-associated habitats. White-tailed deer, acting as carriers of parasitic tick stages, were attracted from ecotone and woodlot areas into modified habitats by a more palatable forage component. The modification of native range plots, which are not suitable as lone star tick habitat, provided areas conducive to deer use and simultaneously unfavorable to ticks. The ability to attract deer to areas unsuitable as tick habitat, and the resultant increased amount of time the deer spend in these areas, will increase the probability of tick detachment in areas in which population propagation is unlikely. The limitation or restriction of habitat favorable for lone star tick propagation by mechanically altering the edaphic conditions of that area is a long-term approach to reducing tick populations. This approach, in conjunction with timely acaricidal treatments and resistant (Zebu: *Bos indicus*) cross-bred cattle, will advance the effectiveness of an integrated management tool for livestock production in the Ozark region of Oklahoma.

## CHAPTER II

## LITERATURE REVIEW

The lone star tick, *Amblyomma americanum* (L.), is the most pestiferous acarine ectoparasite of man, wildlife or domestic livestock in the southeastern and southcentral United States. In Oklahoma this species is most abundant and damaging in the eastern, Ozark mountain region of the State. This three-host tick utilizes an array of warm-blooded mammals and birds to obtain its blood meals in the wild. The lone star tick will also readily attach and feed on man and his domesticated animals when possible (Cooley & Kohls, 1944; Bishopp & Trembley, 1945; Sacktor et al., 1948; Lancaster et al., 1955; Hair & Howell, 1970). Clymer et al. (1970), working in the Ozark region of Oklahoma, reported that all developmental stages of this tick will feed on any available host with the adults found predominately on larger animals. The white-tailed deer, *Odocoileus virginanus* (Boddaert), is the principal host of the lone star tick in the absence of domestic livestock (Bishopp & Trembley, 1945; Brennan, 1945; Clymer et al., 1970; Cooney & Burgdorfer, 1974).

Only recently has assessment of the human and economic impact of this pest on wildlife and domestic livestock been done (Bolte et al., 1970; Meyer et al., 1982; Byford, 1984; Barnard, 1985; Ervin et al., 1985 & 1987). Bolte et al. (1970) estimated the annual fawn mortality due to lone star tick infestations to be as high as 50%. The economic injury level of this tick species infesting cattle has been recently estimated as 10-30 engorging female ticks/animal (Barnard, 1985; Ervin et al., 1985 & 1987).

The multi-host feeding behavior of the lone star tick makes it an excellent suspect vector of many diseases of man, including Rocky Mountain Spotted Fever (Parker et al., 1943), Bullis Fever (Woodland et al., 1943; Anigstein & Anigstein, 1975), Tularemia (Hopla & Downs, 1953; Calhoun, 1954), Q-Fever (Parker & Kohls, 1943), and Tick Paralysis (Swartzwelder & Seabury, 1947).

Tourism and recreational development of the many cultural and natural attributes associated with the Ozark region of northeastern Oklahoma, have been suppressed to a large degree by the excessive populations of the lone star tick (Hair & Howell, 1970). Past investigations have shown the preferred habitat or most likely areas to be inundated with ticks to be brushy areas within meadows or the succession zone (ecotone) between meadows and dense woodlots or areas of dense understory within woodlots (Bishopp & Trembley, 1945; Lancaster et al., 1955; Lancaster, 1958; Semtner et al., 1971a & b; Semtner & Hair, 1973a & b).

The effectiveness of various direct and systemically applied acaricides against lone star ticks has been investigated in the past. The treatment of cattle with standard spray acaricides significantly reduced parasitic and free-living tick populations of larval and nymphal stages within pastures (Barnard et al., 1983). Ivermectin (MERCK MK-933) was found to be an effective systemic treatment against attached female A. americanum, significantly reducing oviposition and/or egg hatch for up to 17 days post-treatment of cattle (Drummond et al., 1981; Lancaster et al., 1982). Mount & Whitney (1984) reported greater than 85% control of all life-stages of lone star ticks for up to six weeks using ultra-low volume chlorpyrifos mists applied for area control with a tractor-mounted blower. Diazinon granules via aerial application for large area tick control was investigated and found successful by Mount (1984). Various other area-wide lone star tick management techniques utilizing acaricides have been studied in recent years (Clymer et al., 1970; Hoch et al., 1971; Cooney & Pickard, 1972; Mount, 1983).

The management practices commonly used for lone star tick control in the livestock industry, will in some instances, lend themselves for use in wildlife management strategies. The mechanical clearing of brush followed by herbicide treatment in an area resulted in a reduction of 58 and 54% of nymphs and adults, respectively (Hoch et al., 1971). Meyer et al. (1982) reported the most effective method of reducing nymphal and adult tick numbers infesting pastured cattle in Arkansas was through habitat modification, while standard spraying techniques provided the least efficient results. Pasture rotation and the use of resistant bovine in areas inundated with A. americanum has been shown to suppress their numbers (Clymer et al., 1970; Garris et al., 1979; Byford, 1984). Mount (1981) investigated the potential of using vegetative management as a control measure against the lone star tick in various Oklahoma parks. The effectiveness of such practices was substantial in decreasing tick numbers by as much as 84% in the larval stage, and 93 and 78% for the nymphal and adult stages, respectively.

Interruption of the lone star ticks' life-cycle, specifically the pre-oviposition period immediately following replete female dissociation from it's host and the forth-coming egg and larval stages, through dessication provides a means by which tick populations can be reduced. Physiological water balance during host-seeking activities for the larval tick is likely a critical factor in it's survival. If the immature tick is unable to attach to a host, therefore remaining exposed to humidities lower than the threshold humidity at which it begins to desiccate, it could ultimately be killed by dessication. Humidities above this threshold will allow the tick to maintain its' water balance by absorption of atmospheric water vapor for extended periods of time (Sauer & Hair, 1971). This threshold humidity is known as the critical equilibrium humidity (Knulle & Wharton, 1964; Knulle & Rudolph, 1982). Lancaster and McMillan (1955), Sonenshine and Tigner (1969), and Semtner et al. (1971a) have reported tick survivability can be substantially reduced in areas of lowered relative humidities and higher soil temperatures. The biological or behavioral effects of habitat modification on the lone star tick provided necessary information in understanding the practical implications of such control strategies.

The study reported herein concentrated primarily on an integrated approach to lone star tick control through habitat modification and manipulation of its' principal host. The use of integrated control practices against this species could lead to more profitable livestock production as well as recreational development in areas of eastern Oklahoma currently heavily infested with this pest. Through consideration of previously established information of the biology, including suitable topographic and vegetative components, experiments were designed to attempt to use white-tailed deer as management "tools". The white-tailed deers' role as the principal host of this species lends itself for use as a transporter of engorging ticks into habitats of unfavorable environmental conditions in which they will be unable to survive or propagate the species.

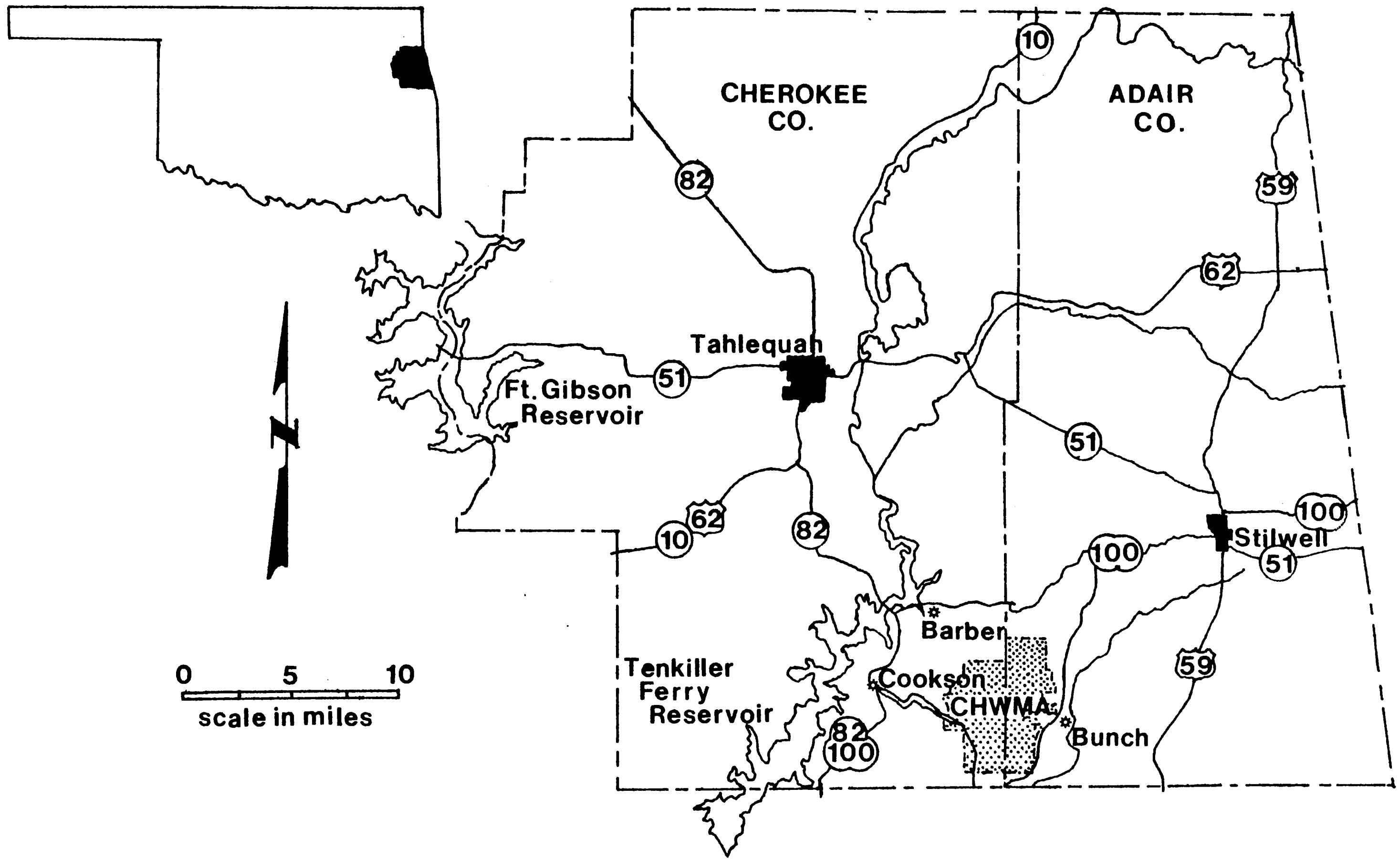
# CHAPTER III

# METHODS AND MATERIALS

## General Study Area Description

The Cookson Hills Wildlife Management Area (hereafter referred to as CHWMA) in Adair and Cherokee counties of northeastern Oklahoma was made available for use by the Oklahoma Department of Wildlife Conservation. The CHWMA is situated 20.8 km southeast of Talequah, 13.6 km southwest of Stilwell, 1.6 km west of Bunch, and 4.8 km east of Cookson (Figure 1). The topographical, soil series, and vegetative character of the CHWMA is typical of much of the available deer habitat of northeastern Oklahoma as well as Arkansas and Missouri. This area was selected as a study site due to a management policy of limited public access, an abundance of wildlife, and the large populations of lone star ticks occurring there. The CHWMA consists of approximately 5,642 ha of rolling, upland oak-hickory forest interspersed with old agricultural fields. The extensive lone star tick and white-tailed deer populations found within this area have been the subject of numerous previous publications (Bolte et al., 1970; Semtner et al., 1971a,b, and 1973; Semtner and Hair, 1973a,b; and Patrick and Hair, 1977).

Figure 1. Map of the Adair and Cherokee Counties Area of Northeastern Oklahoma, Showing Location of CHWMA


CHEROKEE CO.
ADAIR CO.
Tahlequah
Ft. Gibson Reservoir
Stilwell
Barber
Cookson
CHWMA
Bunch
Tenkiller Ferry Reservoir
10
82
51
62
59
100
0 5 10
scale in miles

## Topography

Physiographically the CHWMA is located on the southwestern edge of the Ozark Mountain region. The Cookson Hills are a westward extension of the Boston Mountains which extend from Arkansas into Oklahoma. The approximate elevation extremes within CHWMA are in Walkingstick and Bolin Hollows and on Beaver Mountain. The hollows are approximately 225 m above mean sea level, while the south end of Beaver Mountain is approximately 465 m in elevation (Figure 2). Great variation in the slope of the terrain exists, ranging from three to more than 50% in steepness (Savage, 1976).

## Soils

Soil types within the CHWMA are relatively consistent with those occurring on approximately 78% of the land in Adair, Cherokee, and Delaware counties of northeastern Oklahoma. Primarily, upland forest soils in the Clarksville and Linker series are the most extensive in the area (Cole, 1970). Approximate soil distributions within the CHWMA and the relative amounts of the different soil types are shown in Figure 3 and Table I, respectively. Various physical and chemical properties of the soils occurring on the CHWMA are provided in Table II. More in depth description and

Figure 2. Topograhic Map of Study Area Within CHWMA, Oklahoma

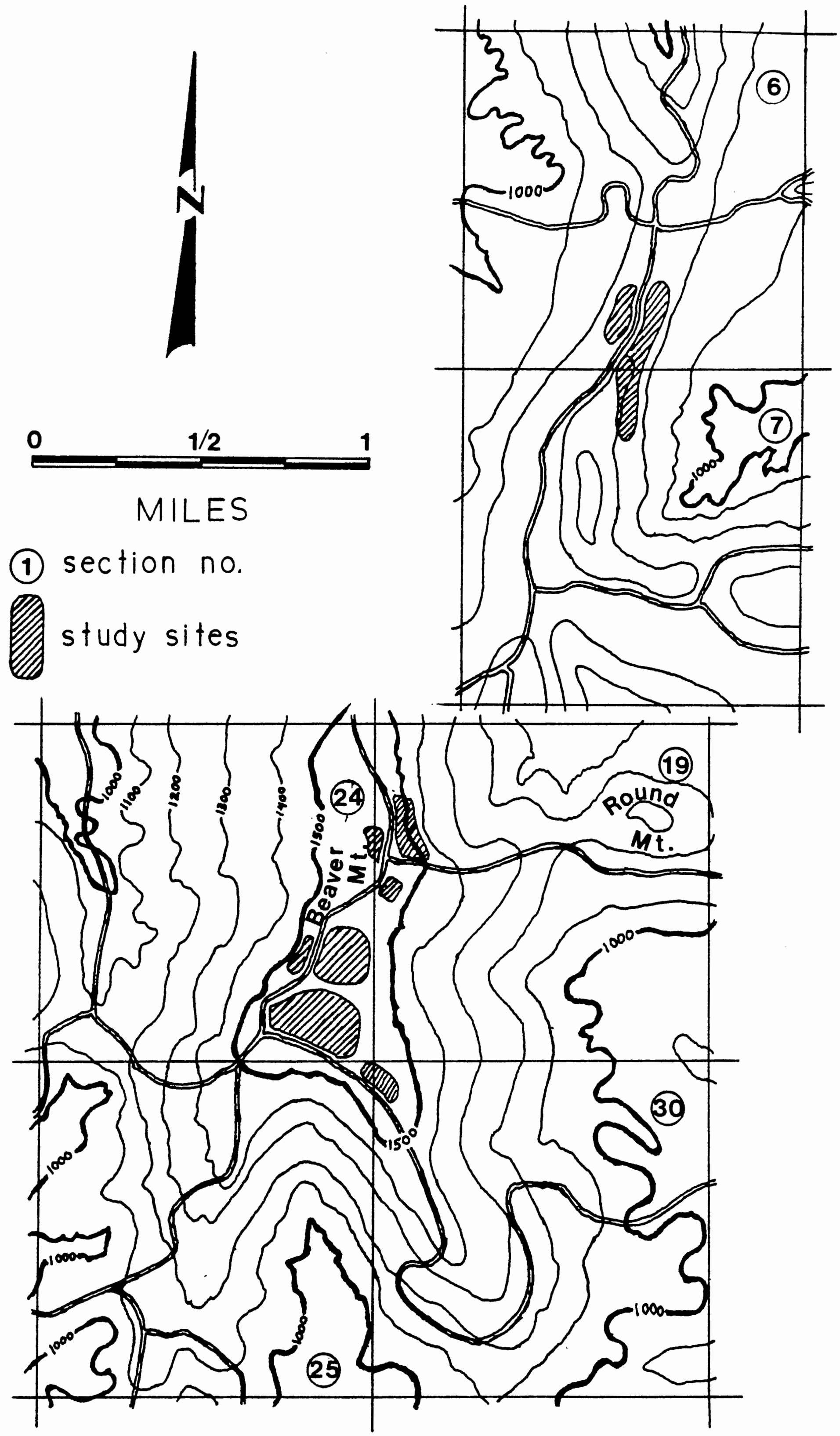

N
0
1/2
1
MILES
1 section no.
study sites
6
7
19
24
25
30
1000
1100
1200
1300
1400
1500
Beaver Mt.
Round Mt.

Figure 3. Soil Map of CHWMA, Oklahoma

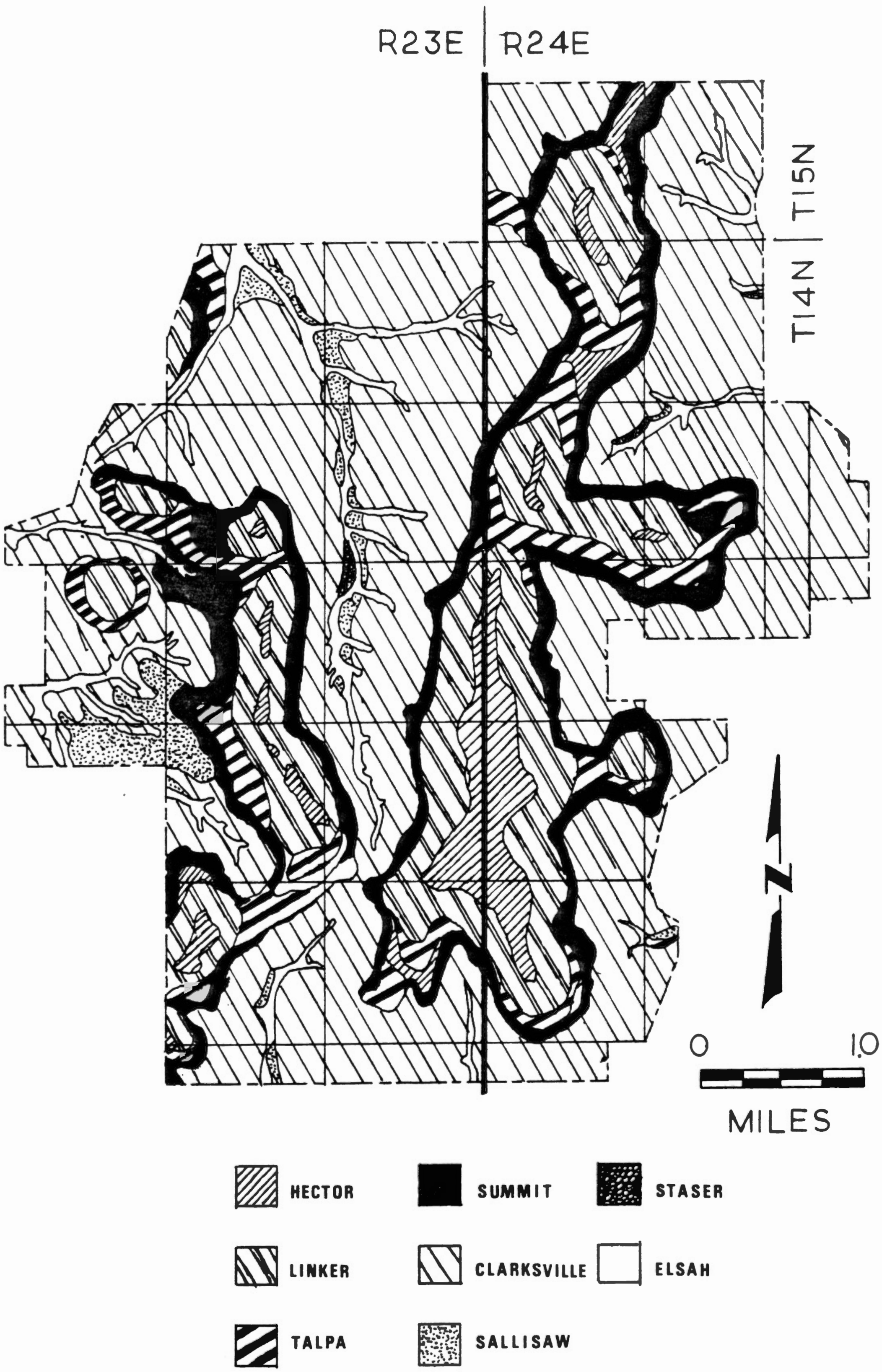

R23E
R24E
T15N
T14N
0
1.0
MILES
N
HECTOR
SUMMIT
STASER
LINKER
CLARKSVILLE
ELSAH
TALPA
SALLISAW

TABLE I

COMPARATIVE AREAS OF DIFFERENT SOILS OF THE COOKSON HILLS WILDLIFE MANAGEMENT AREA BY HECTARES AND BY PERCENT OF TOTAL AREA[1]

| Soil Series | Hectares | Percent |
|---|---|---|
| Clarksville | 3,275 | 58.07 |
| Elsah | 263 | 4.68 |
| Hector | 273 | 4.84 |
| Linker | 829 | 14.70 |
| Sallisaw | 188 | 3.34 |
| Staser | 14 | 0.23 |
| Summit | 526 | 9.34 |
| Talpa | 271 | 4.80 |

[1] Taken from Cole (1970) and Savage (1976).

TABLE II

VARIOUS PHYSICAL AND CHEMICAL CHARACTERS OF SOILS ON THE CHWMA, ADAIR AND CHEROKEE COUNTIES OF OKLAHOMA[1]

| Soil Type[4] | Depth[2] (cm) | Texture | Water[3] (cm) | pH | Permeability (cm/h) |
|---|---|---|---|---|---|
| CL | 0-25.4 | very cherty silt loam | 0.20 | 5.1-5.6 | 16.0-25.4 |
| | 25.4-101.6 | very stony silt loam | 0.15 | 4.5-5.5 | 16.0-25.4 |
| | 101.6-152.4 | chert beds | 0.13 | 4.5-5.5 | 16.0-25.4 |
| EL | 0-152.4 | very gravel loam | 0.13 | 5.6-7.3 | 13.5-50.8 |
| HE | 0-38.1 | fine sandy loam | 0.25 | 5.1-6.5 | 5.1-16.0 |
| LI | 0-15.2 | fine sandy loam | 0.31 | 4.5-6.0 | 1.6-5.1 |
| | 15.2-27.9 | loam | 0.36 | 4.5-6.0 | 1.6-5.1 |
| | 27.9-99.1 | clay loam | 0.43 | 4.5-6.0 | 1.6-5.1 |
| SA | 0-45.7 | gravel silt loam | 0.31 | 5.6-6.5 | 1.6-5.1 |
| | 45.7-81.3 | gravel silt clay loam | 0.37 | 4.5-6.0 | 1.6-5.1 |
| | 81.3-152.4 | very gravel silt clay loam | 0.20 | 4.5-6.0 | 1.6-5.1 |
| ST | 0-60.9 | gravel loam | 0.31 | 6.1-7.3 | 5.1-16.0 |
| | 60.9-109.2 | gravel silt loam | 0.31 | 5.6-7.3 | 5.1-16.0 |
| | 109.2-152.4 | very gravel | 0.13 | 5.6-6.0 | 5.1-16.0 |
| SU | 0-43.2 | silty clay loam | 0.43 | 5.6-7.3 | 0.2-2.5 |
| | 43.2-121.9 | silty clay | 0.38 | 6.1-8.4 | 0.2-2.5 |
| TA | 0-22.9 | silty clay loam | 0.43 | 6.1-7.3 | 0.5-1.6 |

[1] Taken from Cole (1970).
[2] Depth from surface of typical profile.

TABLE II (Continued)

[3] Available water capacity (cm/cm of soil).
[4] Soil types: CL=Clarksville, EL=Elsah, HE=Hector, LI=Linker, SA=Sallisaw, ST=Staser, SU=Summit, TA=Talpa.

explanation of the soil types and geographic character of the CHWMA are available in Cole (1970) and Savage (1976).

## Climate

The general climate of the Cookson Hills region of northeastern Oklahoma is mild and temperate. Seasonal temperature and precipitation fluctuates widely in this area of the Ozark Highlands. The continental climate of this area is influenced by warm, moist air masses from the Gulf of Mexico and cool, dry air from the Arctic and Pacific Ocean (Cole, 1970).

The mean annual temperature ranges from 15-16$^0$C, and the monthly average temperature ranges from 3.3$^0$C in January to 27.8$^0$C in July. Freezing temperatures occur on an average of 85 d from October through April, while only on five of those days does the temperature not rise above freezing (Cole, 1970).

Mean annual percipitation in the Cookson Hills area is ca. 109.2 cm, of which 37% occurs in the spring, 23% in the summer, 21% in the fall, and 19% in the winter (Warth and Polone, 1965; and Cole, 1970).

## Major Vegetative Distribution

The CHWMA is made-up predominately of second-growth oak-hickory forest. Ridge-tops and gentle slopes support grasslands and savannah habitats. Within the management area a variety of habitat types occur as shown in Figure 4, and Figure 5 depicts the specific areas within the management area utilized in this study.

## Study Plot Outlay and Description

Preliminary observations of the CHWMA were conducted during the winter and early-spring of 1985. The suitability of specific areas within the CHWMA were determined based upon known parameters of tick abundance, white-tailed deer abundance, accessibility, and the grazing patterns of the resident elk herd (Joe Fletcher,CHWMA Manager and Dr. Jakie Hair, Adviser, personal communication).

Five different habitat types were desired for use in this study, including: 1) a native range habitat; 2) an improved native range habitat; 3) an ecotone habitat, the succession zone between open meadows and woodlots; 4) an upland oak-hickory woodlot; and 5) a glade-type habitat. Four plots, 0.81 ha in area, were established within each of the desired habitat types. The establishment of four plots of each habitat type allowed four replications of each to be obtained, resulting in a total of 20 plots used in the study. A detailed diagram of the plot layout is provided in Figure 6. The areas, totalling approximately 16.5 ha, included eight hectares of native range, four hectares of ecotone, four hectares of woodlot, and four hectares of glade habitats.

Figure 4. Map of Study Area Within CHWMA, Oklahoma showing Distribution of Major Forest and Grassland Types, Meadows, and Old Fields

= Post Oak - Black Oak Forest Type

= Post Oak - Black Oak Forest Type and Shallow Savannah Range Type

= Red Cedar - Hardwood Forest Type and very Shallow Range Type

= Shortleaf Pine - Oak Forest Type

= Red Oak - White Oak - Hickory Forest Type

= Bitternut Hickory - Black Oak - Elm Forest Type

= Black Oak - Maple Forest Type

= Meadows

= Old Fields

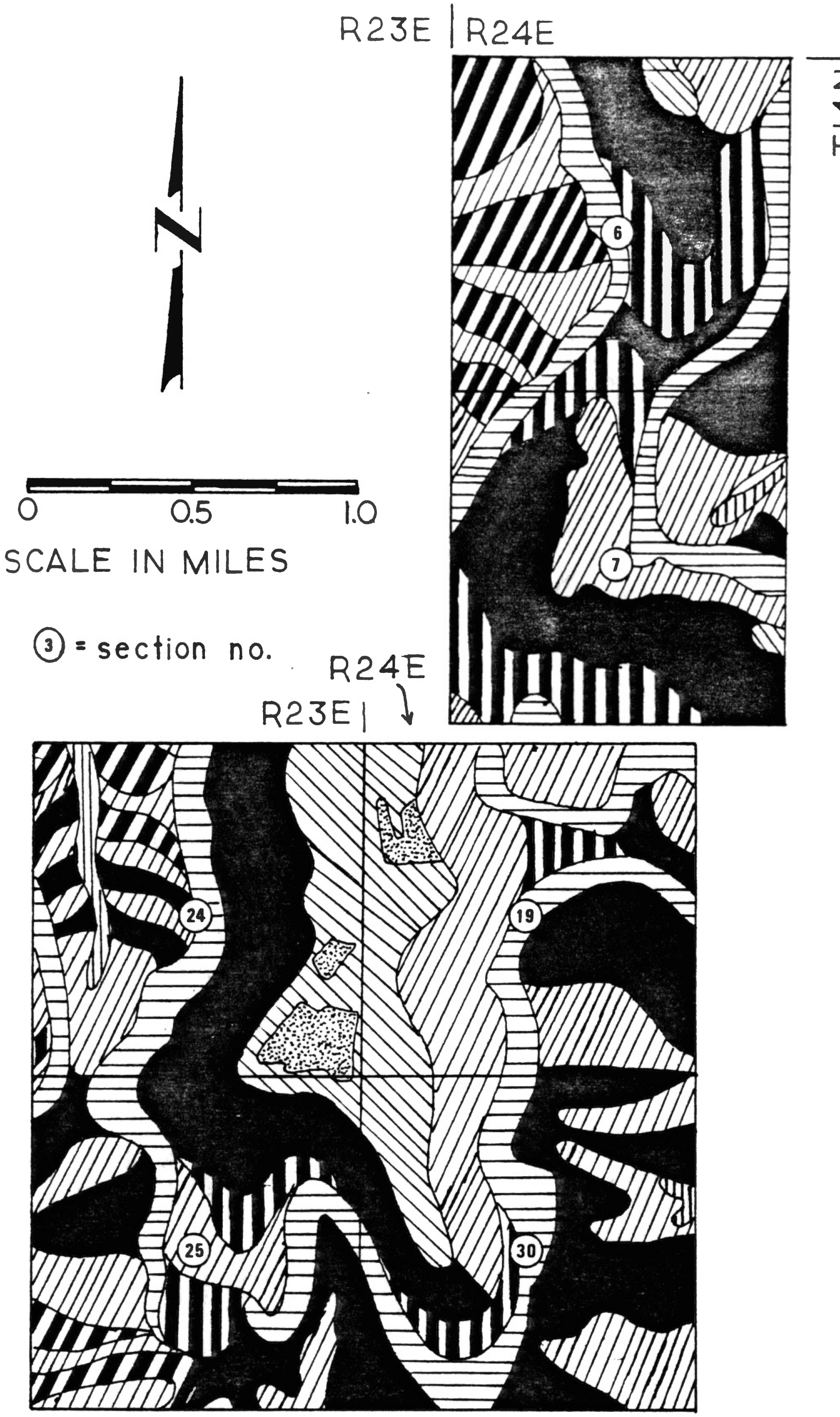

R23E
R24E
T14N
N
0
0.5
1.0
SCALE IN MILES
3 = section no.
6
7
R24E
R23E
24
19
25
30

Figure 5. Map of CHWMA, Oklahoma Showing the Location of Areas Used for Study, 1985 and 1986

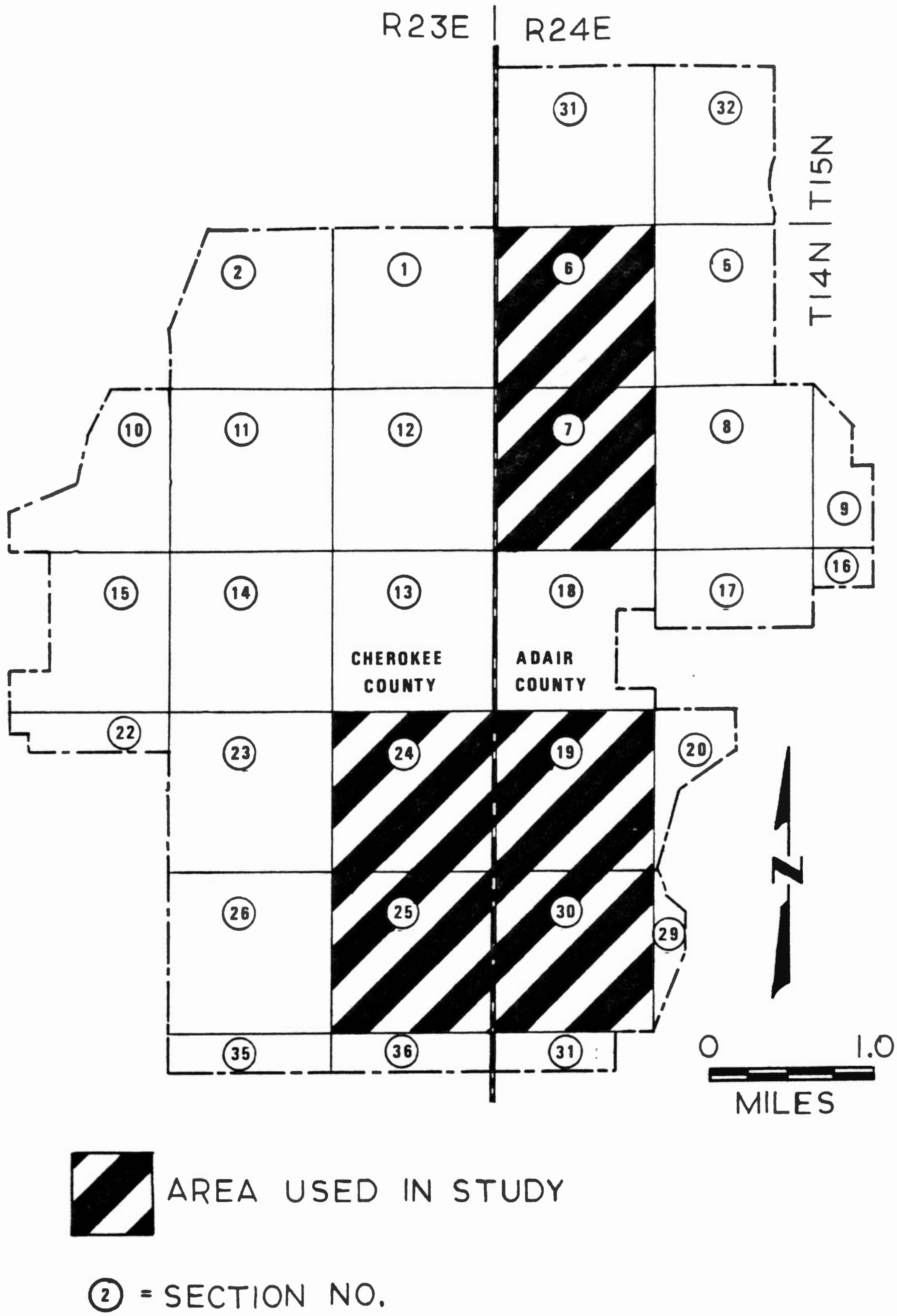
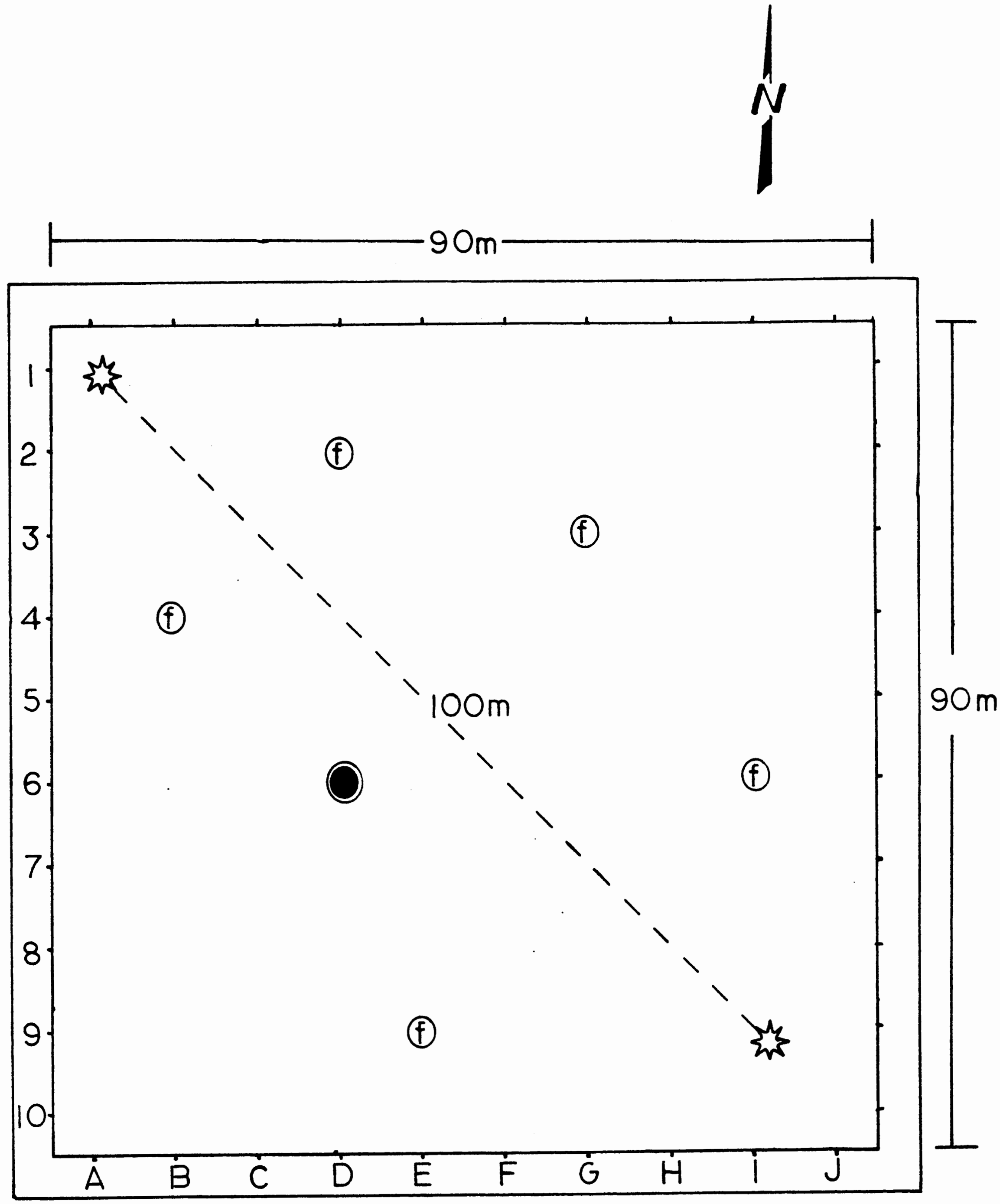

R23E
R24E
T15N
T14N
31
32
2
1
6
5
10
11
12
7
8
9
15
14
13
18
17
16
CHEROKEE COUNTY
ADAIR COUNTY
22
23
24
19
20
26
25
30
29
35
36
31
N
0
1.0
MILES
AREA USED IN STUDY
2 = SECTION NO.

Figure 6. General Dimensions and Layout of Study Plots Used Within CHWMA, Oklahoma during 1985 and 1986

ⓕ = Wildlife Exclusion Cages for Evaluation of Apparent Forage Utilization

◉ = Fenced Area for Exposure of Ticks to Various Habitat Types

✹ = Infrared Transmitter / Receiver Locations on Opposing Ends of Transect


N
90m
90m
100m
1
2
3
4
5
6
7
8
9
10
A
B
C
D
E
F
G
H
I
J
f
f
f
f
f
f

## Plot Establishment

Each plot used in this study, excluding the ecotone plots, was surveyed and the boundary lines established during the months of February and March, 1985. Boundaries were marked on two adjoining sides of each plot with flagged, wooden stakes positioned nine meters apart and a 4.5 m buffer zone on the plot edges. The purpose of marking two of the plot's four sides was to allow a visual grid to be utilized in locating and retrieving tick traps and forage samples. This technique allowed randomization of sampling sites prior to field entry, and also provided the ability to avoid repeated use of specific sites (Figure 6). Forestry flagging was used to indicate boundaries within plots of dense vegetation such as the woodlot and ecotone plots.

The general area within the CHWMA used in this study was sections 24 and 25 of R23E, T14N, and sections 6, 7, 19, and 30 of R24E, T14N (Figure 5).

## Habitat Characterization of Plots

The vegetative component within each plot of the various habitat types is reported in Table III. The quantitative data for number of trees/ha, the biomass produced per hectare, and the formal identification of plant species occurring within each plot was conducted during a three week time period in June, 1986. The botanical

TABLE III

VEGETATIVE ASSOCIATION COMPOSING THE VARIOUS HABITAT TYPES IN THE C.H.W.M.A., CHEROKEE AND ADAIR COUNTIES, OKLAHOMA, 1985, 1986.

WOODLOT

| Plot (replicate) | Trees[a] /ha. | Biomass[b] Kg/ha. |
|---|---|---|
| 1 | 1,249.51 | 0.0 |
| 2 | 1,499.41 | 0.0 |
| 3 | 1,199.53 | 0.0 |
| 4 | 1,199.53 | 133.948 |

Species present:

Trees;

Elm, American (*Ulmus americana* L.)
Hickory, bitternut [*Carya cordiformis* (Wang.)]
Hickory, mockernut [*C. tomentosa* (Nutt.)]
Hickory, shagbark [*C. ovata* (Mill.)]
Oak, black (*Quercus velutina* Lam.)
Oak, blackjack (*Q. marilandica* Muenchh.)
Oak, northern red (*Q. rubra* L.)
Oak, post (*Q. stellata* Wang.)
Oak, white (*Q. alba* L.)
Sassafras [*Sassafras albidum* (Nutt.)]

Shrubs, herbs and grasses;

Buckbrush (*Symphoricarpos orbiculatus* Moench)
Panicum (*Panicum* spp.)
Saw greenbriar (*Smilax bona.-nox.* L.)

ECOTONE

| Plot (replicate) | Trees /ha. | Biomass[b] Kg/ha. |
|---|---|---|
| 1 | scattered | 2,902.865 |
| 2 | scattered | 1,943.240 |
| 3 | scattered | 2,516.016 |
| 4 | scattered | 2,254.119 |

TABLE III (Continued)

Species present:
    Trees;
        Elm, American
        Elm, winged (*U. alata* Michx.)
        Oak, post
        Persimmon (*Diospyros virginiana* L.)
        Sassafras

    Shrubs, herbs and grasses;
        Blackberry (*Rubus* spp.)
        Buckbrush
        Clover, tick (*Desmodium* spp.)
        Greenbriar, saw
        Johnsongrass [*Sorghum halepense* (L.)]
        Lespedeza, sericea [*Lespedeza cuneata* (Dumont G. Don)]
        Panicum, beaked [*Panicum anceps* (Michx.)]
        Sumac, winged (*Rhus copallina* L.)
        Wildrye, Virginia (*Elymus virginicus* L.)

GLADE

| Plot (replicate) | Trees[c] /ha. | Biomass[b] Kg/ha. |
|---|---|---|
| 1 | 328.51 | 1,840.280 |
| 2 | 353.21 | 3,101.787 |
| 3 | 372.97 | 2,985.832 |
| 4 | 249.47 | 2,641.967 |

Species present:
    Trees;
        Ash (*Fraxinus* spp.)
        Elm, winged
        Hackberry (*Celtis* spp.)
        Persimmon

    Shrubs, herbs and grasses;
        Bluestem, big (*Andropogon gerardi* Vitman)
        Bluestem, broomsedge (*A. virginicus* L.)
        Bluestem, little (*A. scoparius* Michx.)
        Grama, hairy (*Bouteloua hirsuta* Lag.)
        Grama, sideoats [*B. curtipendula* (Michx.)]

TABLE III (Continued)

NATIVE RANGE

| Plot (replicate) | Trees /ha. | Biomass[d] Kg/ha. |
|---|---|---|
| 1 | 2.0 | NA |
| 2 | 1.0 | NA |
| 3 | 3.0 | NA |
| 4 | 0.0 | NA |

Species present:
Trees;
Oak, black
Oak, post

Shrubs, herbs and grasses;
Bluestem, big
Bluestem, broomsedge
Bluestem, little
Bromegrass (*Bromus* spp.)
Foxtail (*Setaria* spp.)
Johnsongrass
Lespedeza, Korean (*L. stipulacea* Marim.)
Lespedeza, Sericea
Panicum
Unolia, broadleafed (*Unolia latifolia* Michx.)

IMPROVED RANGE

| Plot (replicate) | Trees /ha. | Biomass[d] Kg/ha. |
|---|---|---|
| 1 | 0.0 | NA |
| 2 | 1.0 | NA |
| 3 | 0.0 | NA |
| 4 | 0.0 | NA |

Species present:
Trees;
Oak, post

TABLE III (Continued)

Shrubs, herbs and grasses;
Bluestem, big
Bluestem, little

Clover, red (<u>Trifolium pratense</u>)[e, f]
Fescue, Kentucky 31 (<u>Festuca arundinacea</u>)[e]
Foxtail
Johnsongrass
Ryegrass (<u>Lolium multiflorum</u>)[f]
Unolia, broadleafed

---

Trees[a] = Number of trees/ha. calculated from 2 - 100 m line transects randomly established in each woodlot plot (4 reps.)

Biomass[b] = Average Kg/ha. calculated from 2 - 0.5 $m^2$ samples collected from 1 - 100 $m^2$ belt transect establishedin each plot (4 reps.)

Trees[c] = Total number of trees/plot counted in each glade plot due to sparse distribution (4 reps.)

Biomass[d] = Total biomass in native and improved range plots monitored biweekly throughout study for forage production and appearent consumption estimations, data reported in Fig. 15

[e] = Domestic forage species planted in improved range plots for 1985, constituting dominant prevalence of vegatative component

[f] = Domestic forage species planted in improved range plots for 1986, constituting major prevalence of vegetative component.

nomenclature of reported species follows that of Featherly (1946), Waterfall (1970), and Hoffman (1979).

The number of trees, those with a basal trunk diameter greater than 10 cm and/or greater than two meters in height, were counted along two - 100 X 2 m belt transects established in each woodlot plot. This method is a modification of a tree abundance estimation technique described by Phillips (1959). The number of trees/ha was mathematically calculated from the average of the counts recorded for each transect within each plot (Table III).

The average kg/ha of biomass and the identification of plant species witin each plot was determined from a 100 m line transect randomly established in each of the 20 plots. Two hand-clipped forage samples (0.5 $m^2$) were removed from each transect and transported to the laboratory for identification to species and dry matter yield data, similar to the technique of Baker (1978). Forage biomass and species occurrence in the various habitat types is reported in Table III.

## Native Range Improvement

Four native range areas, each containing at least two hectares, were established and subdivided into eight plots as described previously. From the eight native range plots, four separately located plots were arbitrarily designated for range improvement procedures. These plots were sampled for soil fertility prior to any cultivation in 1985 and 1986. The Agronomy Soil Testing Laboratory, Oklahoma State University, Stillwater, conducted soil fertility analysis and the recommended remedies for soil nutrient deficiencies were implemented.

Native range improvements made in February, 1985 consisted of the incorporation of 2,220 kg/ha of agricultural lime and 445 kg/ha of 10-20-10 (N-P-K) fertilizer on all improved plots. In early-March of 1985, each plot was cultivated to a depth of ca. 20 cm, via a deep-breaking plow, and seeded with red clover (Trifolium pratense) and Kentucky-31 tall fescue (Festuca arundinacea). A tractor mounted Cyclone® spreader was used to broadcast the red clover and tall fescue seeds at a rate of 16 and 18 kg/ha, respectively.

Forage improvement of the native range in 1986 was conducted similar to that of 1985. However, soil nutrient analysis and recommended remedies were applied during October of 1985. Each plot received 2,220 kg/ha of agricultural lime. Two of the four replicates received 278 kg/ha of 6-24-24 (N-P-K) fertilizer, while another of the plots received 222 kg/ha of 0-0-60 (N-P-K) fertilizer. Broadcast seeding of red clover and perennial ryegrass (Lolium perenne) was performed during late October, 1985 on each of the plots designated as improved native range habitat.

## Environmental Monitoring

The long-term goal of native range modification was to increase the temperature and lower the relative humidity, producing a microhabitat unsuitable as lone star tick habitat. In addition, a forage component more palatable or attractive to deer would entice deer to spend more time in these areas, theoretically increasing the number of replete ticks dissociating from the host in this unfavorable habitat type. Several techniques were utilized to monitor the ambient and edaphic climatic conditions within each of the five habitat types.

Macro-environmental Conditions. The ambient temperature and relative humidity occurring 30 cm above the soil surface, within one representative plot of each habitat type, was monitored continuously during both years of the study. This was accomplished using BELFORT® seven day hygrothermographs, housed in standard weather stations. The hygrothermographs were operated continuously from 14 May - 22 August, 1985, and from 11 March - 9 September, 1986.

Micro-environmental Conditions. Knowledge of the soil moisture content and soil temperature within the various habitat types was essential in determining the suitability of these areas for lone star tick survival. The soil surface temperature was recorded once weekly from within each of the

20 plots during 1985 to allow a relative comparison of habitat factors. This was accomplished using a probe thermometer placed horizontally on the soil surface at the same approximate location within each plot during a two hour time period. This method of monitoring soil surface temperature allowed only limited accuracy in comparing the dynamic edaphic conditions occurring between and within particular habitat types. It was therefore decided to utilize continuous recording instrumentation in future study.

During 1986, TEMP-SCRIBE®, seven day, continuous recording, remote thermographs were used to monitor soil temperature. A representative plot of each habitat type was monitored for soil temperature with the remote thermographs housed in the weather stations with the hygrothermograph units. The remote probes were positioned two meters northeast of each weather station.

Weekly data of the percentage soil moisture content was obtained gravimetrically during both years of the study. Volume-equivalent soil samples, the top six centimeters of surface soil, were removed from a predetermined location within each of the 20 plots. Soil samples were placed into soil-tins, sealed with plastic adhesive tape, and transported to the laboratory. The soil samples were weighed, oven dried for at least 48 h at 105$^{o}$C, and reweighed to obtain the water weight lost from the sample for calculation of percentage soil moisture content.

## Non-Parasitic Tick Abundance

The survivability of lone star ticks within specific habitat types can be determined through many methods, one of these methods is by monitoring the tick populations occurring there. The occurrence and abundance of free-living, host seeking life stages of A. americanum was monitored weekly in each of the 20 established plots. The tick sampling method was similar to that described by Wilson (1972), Kinzer (1975), and Grothaus and others (1976), in which carbon dioxide ($CO_2$) baited sticky traps were used to capture indigenous tick populations. Tick traps were constructed of a square section of 0.36 cm masonite (936 $cm^2$) onto which a length of 5.08 cm wide masking tape was applied to the upper edge of the trap base. One half of the tapes width was rolled back onto itself to expose a sticky surface capable of entangling ticks attempting to cross it. A 0.47 l plastic reservior cup, containing ca. 228 g of dry ice, was placed in the center of each trap base.

Tick traps were placed at specific sites within each plot determined from random site drawings prior to field entry. The staking of the plot perimeters, as described previously, allowed efficient trapping site location and prevented repeated use of any single site. Each trap site location consisted of 81 $m^2$ (0.02 ha) due to the strategic outlay of the plots. Five, $CO_2$-baited traps were operated for a minimum of three hours in each plot. The traps were recovered and transported to the laboratory and actual counts of all lifestages were recorded.

Weekly tick trapping within each of the 20 plots was initiated 14 May 1985, and 12 March 1986, and continued until 20 August 1985, and until 13 September 1986. Due to low larval tick captures in 1985, the standard tick flagging technique as described by Clymer et al. (1970) was utilized as a supplemental survey tool in July and August of 1986. The flagging method involved the use of a drag-cloth pulled over the ground vegetation for 25 steps and the number of ticks adhering to the cloth counted. Four flagging samples were taken in each plot and the number of ticks recovered was recorded.

## Tick Survival and Fecundity In Different Habitats

Evaluations of the suitability of the various naturally occurring habitat types, as well as the effects of habitat modification, on the survival and fecundity of lone star ticks were made during both years of this study. Techniques similar to those used in *A. americanum* field biology studies by Semtner et al. (1971, 1973), in which ticks were exposed to field conditions in cages or arenas, were used in this study. Unengorged and replete, female, lone star ticks were exposed in each of the different habitat types to determine their survival and fecundity, respectively.

The survival potential of five unengorged, female *A. americanum* was observed weekly following exposure within the various habitats. Ticks were exposed at weekly intervals within each of the four replicates of each habitat type during 1985, with the first exposure initiated 3 May and subsequent exposures made until 26 June. Unengorged female lone star ticks exposed within each habitat type in 1985 were obtained from Oklahoma State University Medical Entomology Laboratory colony stock. All ticks exposed were ca. 90-120 d post-molt, healthy appearing, active specimens. Ticks used for survival evaluations in 1986 were also obtained from colony stock, but were transported to the CHWMA in October 1985 and allowed to acclimate to the field conditions prior to use in the study. Eleven, weekly exposures of flat females were made in 1986 beginning 22 March and continuing until 25 June.

Weekly observations of lone star tick survival consisted of approaching each cage, avoiding disturbance of its' resident ticks, and recording the location (height and direction) within the cage of each tick. Following initial observation, any inactive ticks were stimulated by human breath to determine if they were dead. Observations were recorded for each group of ticks during both years until all ticks were dead or quiescent.

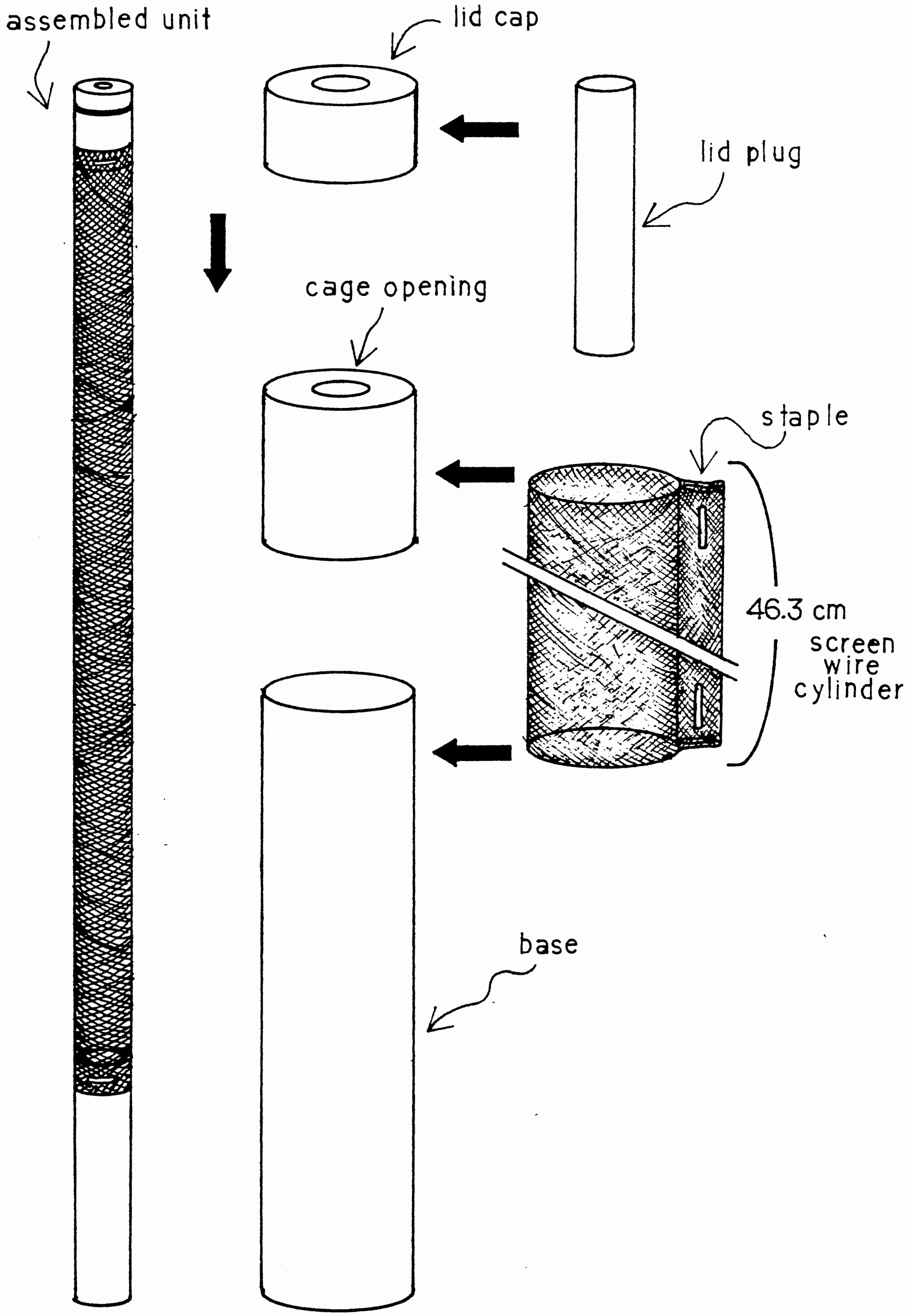
The fecundity, as measured by the oviposition success and the egg viability of offspring, of three replete _A. americanum_ was observed weekly in each plot during 1985 and 1986. Three exposures of replete females were made during 1985, the first on 5 May, the second on 16 May, and the third on 3 June. Exposures of ticks in 1986 for fecundity evaluation consisted of four release dates; 6 April, 27 April, 22 May, and 12 June. Replete female ticks exposed in 1985 and 1986 were obtained from the Medical Entomology laboratory colony, fed to repletion on sheep, and transported to the field within 48 h following dissociation from the host animal. All ticks used for field exposure were screened for apparent health prior to use in the study.

## Cage / Arena Design

To facilitate the exposure of ticks and allow efficient, accurate observations of the survival and fecundity within each habitat type, two different tick container designs were used.

_Unengorged Female Tick Cages_. The cages used to expose flat ticks to the various habitat types were constructed primarily of 2.54 cm (dia.) wooden dowel rods and aluminium, standard window screening (Figure 7). Each cage unit

Figure 7. Cage Design for Exposure of Unfed Female Lone Star Ticks to Various Habitat Types for Observation of Survival and Behavior, 1985 and 1986


assembled unit
lid cap
lid plug
cage opening
staple
46.3 cm
screen
wire
cylinder
base

consisted of a lid cap and plug assembly fashioned from a 1.27 cm (L) section of 2.54 cm dowel with a 0.96 cm (dia.) hole drilled through it. A 5.00 X 0.96 cm (L X dia.) wooden dowel was then inserted into the lid cap hole and adhered in place (Figure 7). A 2.54 X 2.54 cm (L X dia.) section of dowel was then cut and a 0.96 cm (dia.) hole drilled through it, serving as the cage opening. Next, a 15.25 cm length of dowel was cut to serve as a base for the cage unit. A 45.72 X 12.72 cm (L X width) rectangle of standard aluminium screen wire is fashioned into a cylinder (45.72 X 2.54 cm, L X I.D.) and stapled to retain its shape (Figure 7). The edges of the screen wire cylinder were rolled together and the resulting seam was sealed with silicone caulking.

Engorged Female Tick Arenas. The design of the arenas used to expose engorged female ticks to the various habitat types in 1985 and 1986 are shown in Figure 8 and 9, respectively. The arenas used in 1985 were constructed of length of 10.3 cm (dia.), SDR-Poly vinyl chloride (PVC) pipe, cut into an arena base (10.3 - 12.9 cm), a sleeve (5.08 cm), and a lid (2.54 cm) (Figure 8). The sleeve was modified with a sizing cut to allow compression of its' diameter to facilitate insertion into the lid unit. A portion of nylon mesh (0.24 cm weave) cloth was positioned between the lid and sleeve components as they were fitted together. Pop-rivets were then utilized to fasten the

Figure 8. Arena Design for Exposure of Engorged Female Lone Star Ticks to Various Habitat Types for Observation of Survival, Oviposition, and Larval Eclosion, 1985

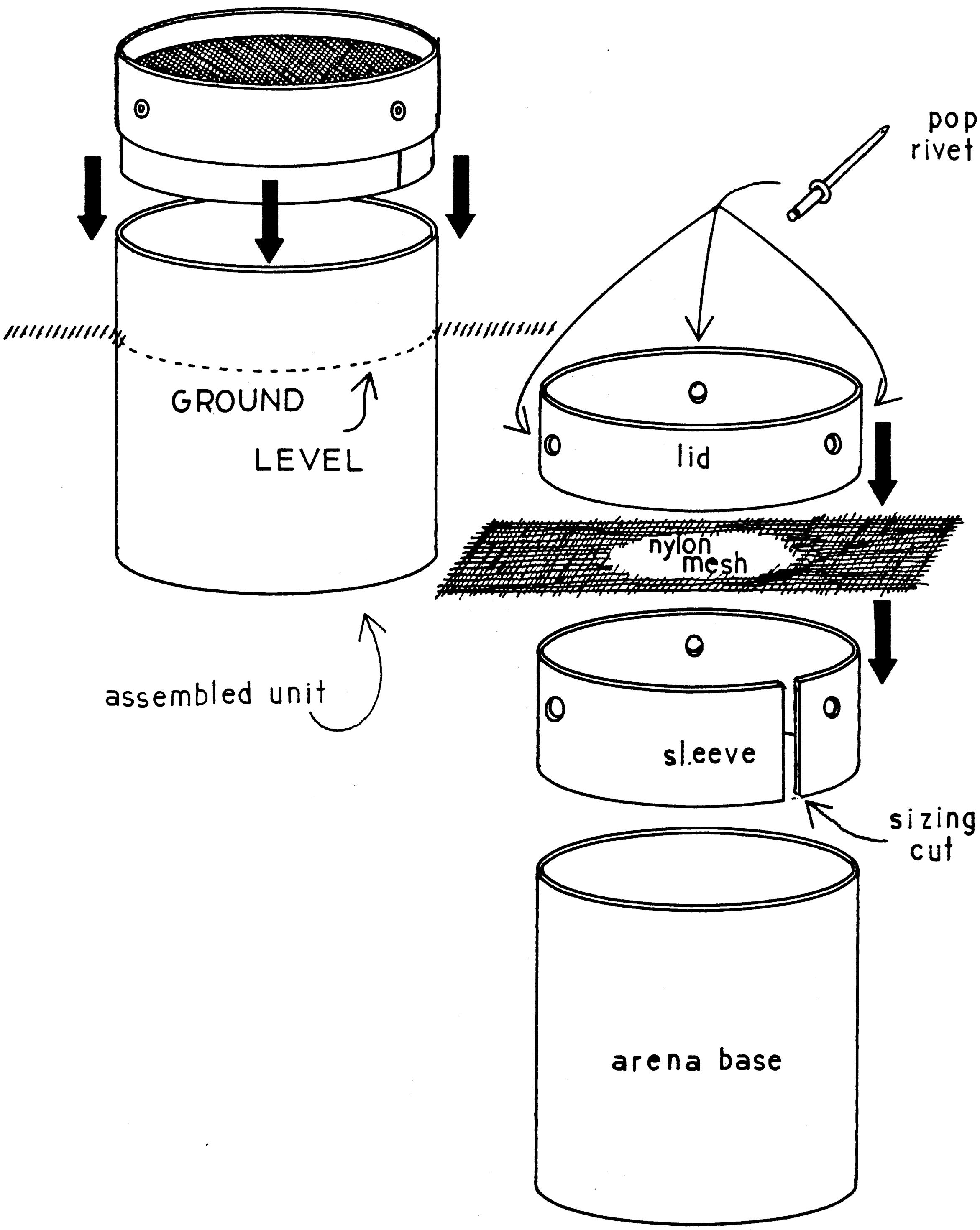
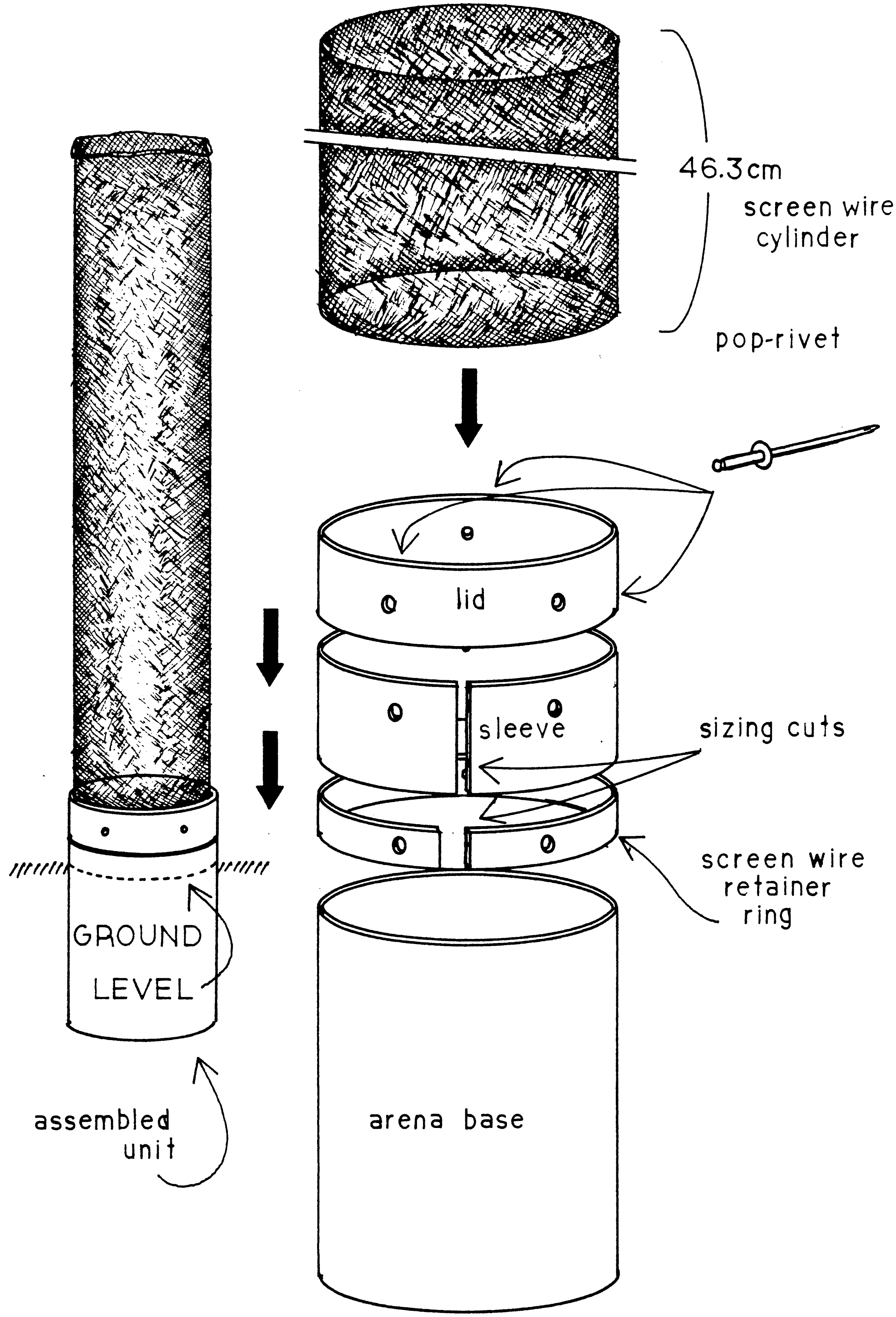

pop-
rivet
GROUND
LEVEL
assembled unit
lid
nylon
mesh
sleeve
sizing
cut
arena base

Figure 9. Arena Design for Exposure of Engorged Female Lone Star Ticks to Various Habitat Types for Observation of Survival, Oviposition, and Larval Eclosion, 1986


46.3cm
screen wire
cylinder
pop-rivet
lid
sleeve
sizing cuts
screen wire
retainer
ring
GROUND
LEVEL
assembled
unit
arena base

lid-sleeve unit securely, excess nylon mesh was trimmed away, and silicone caulking was used to seal any open spaces (Figure 8). To prevent larval tick escape from these arenas, TACK-TRAP® was painted on the inner surface of the sleeve component. With the sleeve unit compressed to fit inside the lid ring, insertion of the entire lid-sleeve combination into the arena base for containment of ticks was facilitated.

It was determined in 1986 that an improved engorged female tick arena design was needed due to the observed escape of larvae from the arenas used in 1985. Upon hatching and the initiation of host seeking behavior of the larval ticks, they would climb available vegetation within the arena, avoiding the TACK-TRAP®, and escape from the arena on external vegetation.

The arenas used in 1986 were constructed similar to those used in 1985, but modified with an aluminium screen wire cylinder (46.3 X 10.3 cm, L X dia.) to prevent larval escape on external vegetation (Figure 9). The screen wire cylinder was positioned inside the sleeve with a screen wire retainer ring. Approximately 10 cm of the screen wire cylinder was folded over the retainer ring and into the lumen of the cylinder to form a secondary ceiling to block vegetation within the arena. This design prevented any direct contact between external and internal vegetation surrounding the arena. TACK-TRAP® was painted on the sleeve as in the 1985 arenas to prevent larval escape up the walls of the unit.

Cage / Arena Placement

All ticks were exposed within a fenced enclosure (ca. 16 $m^2$) established in each plot of each of the five habitat types. The forage component within each of these enclosures in the native and improved range plots was maintained consistent to that outside the enclosure.

The cages used for unengorged tick exposure were placed into pre-piloted holes in the soil to a depth at which the floor of the cage was ca. 2 cm below the soil surface. The placement of the cage floor slightly below the soil surface allowed the ticks to be in direct soil contact through the screen wire walls of the cage.

Arenas used to expose the engorged ticks to the various habitat types were positioned in the soil to a depth at which ca. 1.9 cm of the cage base was above the soil surface. The soil surface, which included leaf litter and duff layer, served as the floor of the arenas allowing the replete females the ability to burrow into the soil prior to oviposition. A hole piloting device was used in the arena placement to minimize disruption of the soil surface during installation.

## Visitation and Utilization of Native and Improved Range Habitats

The frequency of visitation and utilization of the forage component of the native range and improved native range plots was used as a means of quantifying and comparing the time spent in each of the habitat types by white-tailed deer. Several techniques were used in monitoring and evaluating the white-tailed deers occurrence and usage of the study areas to complement each other in providing more accurate interpretations of the actual deer behavior and forage utilization.

### Deer Pellet Group Counts

Weekly counts of the number of deer pellet groups occurring on belt transects (100 X 2 m), established within each plot, were recorded during 1985 and 1986. This method was similar to those described by Hosely (1956). Recognized pellet groups were immediately recorded, crushed and removed from the transect proper, to prevent later recount (Ferguson, 1955). Forage height in each of the transects was maintained at ca. 10 cm to facilitate more accurate observations.

<u>Apparent Forage Utilization Estimation</u>

The utilization or consumption by white-tailed deer of the available forage within the two habitat types was estimated through quantitative comparison of accessible and inaccessible areas within each plot. During both years of the study, five deer exclosures were constructed at random sites in each of the native and improved range plots. Circular, non-climb fencing exclosures (ca. 1.5 m dia.) were erected prior to study initiation. All samples taken from outside the exclosure were taken at ca. 3 m from the exclosure, with samples from the same week spotted in the same direction from the exclosure in all plots.

<u>1985</u>. The forage height inside and outside the deer exclosures was measured biweekly at each of the five exclosures within each plot of the two habitat types for comparison. These data were found to be highly variable and inaccurate due to many ambiguous factors, such as compensatory regrowth, species palatability, and trampling by wildlife. For these reasons the means of determining forage consumption was modified for 1986 observations.

<u>1986</u>. Estimates of the apparent forage consumption made in 1986 utilized a technique similar to that described by Cook (1962), in which biomass samples were taken from within and without exclosures and their dry matter weights

were compared. Four samples of forage from each plot were taken using a 0.5 $m^2$ quadrate placed at a random sample site, and the forage within clipped and bagged. Forage samples within the exclosures were taken at four times throughout the season (14 May, 18 and 26 June, and 14 August), and each habitat was replicated four times. Samples were taken to the laboratory and oven dried at $60^0$C for 48 h, weighed, and data recorded.

## Infrared Transect Procedure

A more accurate, continuous method of monitoring the frequency and degree to which white-tailed deer visited the native and improved range habitat plots was needed during 1986. A system which would not interfere with the normal behavior of the deer or the environment in the area of study. It was determined that an infrared beam used to transect an area, and equipped to record each beam interruption, would be an effective means of monitoring deer visitation. Infrared beam transmitters and receivers (ADEMCO; INFRARED INTRUSION DETECTORS®, Model No. 1290, Syosset, New York) were positioned at opposite ends of 100 m transects established in two of the native range plots and in two of the improved range plots. Units were mounted on angle-iron frames and concreted in the ground. Beam height was calibrated at 70 cm above ground level to avoid small wildlife interference. The sensitivity of the infrared receiver was adjusted to record all beam interruptions greater than 0.06 s, this prevented recording birds or air-borne debris interference.

### Visual Observations of Deer Behavior

To complement and lend validity to the previously described deer visitation/utilization monitoring techniques, actual visual observations of deer occurrence was monitored in 1986. Nightcounts of the deer observed along a predetermined, repeated route were made using spotlights shone from a slow moving vehicle, similar to the technique of Harestad and Jones (1980). This method is often used as a population census tool by wildlife conservationists, however, in this study it was used only as a means of comparing deer occurrence between plots of different habitat types. Nightcounts were recorded weekly, weather permitting, between the hours of 2100 and 2300 CST.

## Forage Production of Native and Improved Native Range Habitats

The production of forage biomass within each of the native and improved native range plots was estimated biweekly throughout the duration of both years of study. The kg/ha of dry matter yield was determined using a method described by Baker (1978) in which a 0.5 $m^2$ sample area was hand clipped, oven dried ($60^0$C for 48 h), and weighed to obtain kg dry matter produced. Analysis of digestable protein content of the forage samples taken on 5, 19, and 26 June 1986 were performed to provide information of the nutritional quality within each of the habitat types.

The improved native range plots were harvested for hay upon observance of blooming clover, during 1985 and 1986. Harvest was performed 2 July 1985, and 5 June and 3 July 1986. The native range plots were mowed at a height of ca. 10-12 cm at the same time hay was being harvested on the improved plots (previous management practice at the CHWMA).

## Statistical Analysis

This study was implemented using a randomized block design in which each of the different habitat types was considered a treatment. Four replications of each treatment were obtained from the the four plots of each habitat type. The location for placement of the various sampling devices or units within each plot of each treatment type, was randomized. Tick trapping locations, forage sample locations, and soil character samples for each observation period were drawn at random from a previously prepared pool of sites. Each site was only used for sampling one time during a season. Comparison of means ($\bar{x}$) among and between treatments for data derived from trapping, forage component observations, and deer utilization was made using Duncan's Multiple Range Test (Duncan, 1955). Significant differences between treatments were determined using Duncan's Multiple Range Test at the ($P \leq 0.05$) level (S.A.S., 1985).

# CHAPTER IV

# RESULTS AND DISCUSSION

## Environmental Monitoring of Different Habitat Types

The suitability of any specific habitat to support a living organism population is highly dependent on the ambient (macro-environmental) and edaphic (micro-environmental) conditions. These environmental conditions are the result of a complex of contributing factors which singularly must be evaluated in the determination of the overall effect. The temperature and humidity, or moisture, are two of the major factors contributing to the habitats environmental overall suitability and potential for biotic support.

### Macro-environmental Conditions

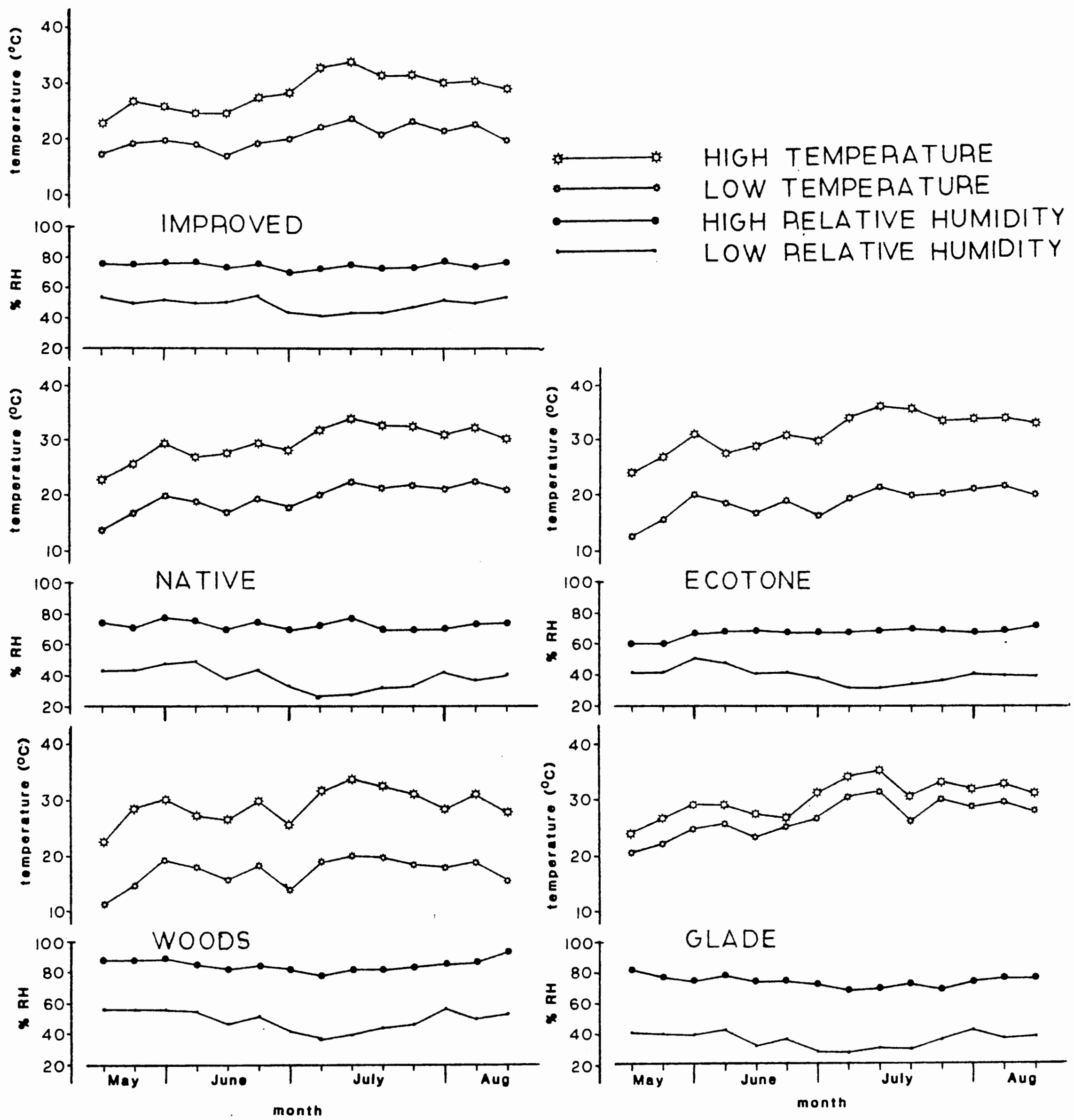
Continuous monitoring of the ambient temperature and relative humidity within each of the various habitat types provided useful information in determining the suitability of these habitats for lone star ticks. The seven-day average high and low temperatures and high and low percent relative humidities recorded for each habitat are illustrated in Figures 10 and 11 for 1985 and 1986, respectively.

Comparison of the macro-environmental trends during both years, 1985 and 1986, for the improved native range plots with those of the other habitat types (Figures 10 and 11) indicates several significant factors. There appears to be very similar ambient conditions existing in the improved and native range plots and early season similarities with the glade habitat. The improved habitat was consistently more variable in its' temperature ranges than the woodlot and ecotone plots.

## Micro-environmental Conditions

Soil Temperature. The mean ($\bar{x}$) soil surface temperatures monitored in each of the five habitat types in 1985 are shown in Table IV. There were no statistically significant ($P \leq 0.05$) differences between the improved and native range habitat plots. The woodlot habitat was consistently the coolest throughout the season, and was significantly ($P \leq 0.05$) cooler than both the improved and the native habitat (Table IV). The improved range habitat had significantly ($P \leq 0.05$) higher soil surface temperatures than those recorded for the ecotone plots after 12 June, with peak differences of approximately 25$^{o}$F on 11 July. Soil surface temperatures in the glade were consistently and significantly ($P \leq 0.05$) the highest of all

Figure 10. Mean ($\bar{x}$) Weekly High and Low Ambient Temperatures and High and Low Percent Relative Humidity for Five Different Habitat Types, CHWMA, Oklahoma, 1985



temperature (°C)
40
30
20
10
% RH
100
80
60
40
20
IMPROVED
NATIVE
ECOTONE
WOODS
GLADE
HIGH TEMPERATURE
LOW TEMPERATURE
HIGH RELATIVE HUMIDITY
LOW RELATIVE HUMIDITY
May
June
July
Aug
month

Figure 11. Mean ($\bar{x}$) Weekly High and Low Ambient Temperatures and High and Low Percent Relative Humidity for Five Different Habitat Types, CHWMA, Oklahoma, 1986

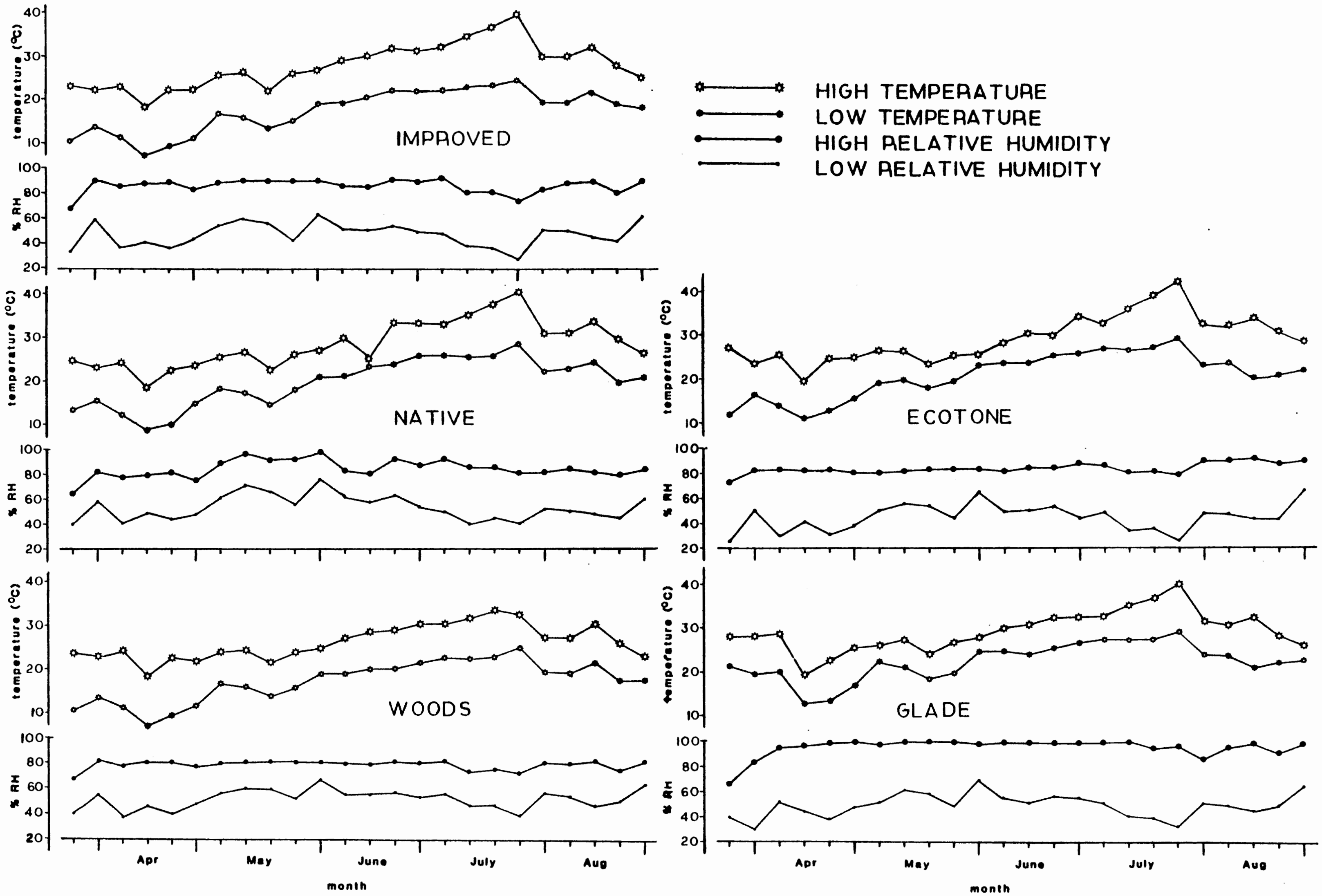

HIGH TEMPERATURE
LOW TEMPERATURE
HIGH RELATIVE HUMIDITY
LOW RELATIVE HUMIDITY
IMPROVED
NATIVE
ECOTONE
WOODS
GLADE
temperature (°C)
% RH
Apr
May
June
July
Aug
month

TABLE IV

MEAN ($\bar{X}$) SOIL SURFACE TEMPERATURE OCCURRING IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 12-VI | 74.25 AB | 77.63 AB | 67.25 C | 71.00 AC | 79.25 D |
| 19-VI | 82.00 A | 82.50 A | 76.00 B | 77.75 B | 89.00 C |
| 27-VI | 81.75 A | 81.25 AB | 72.50 C | 75.25 BC | 94.25 D |
| 04-VII | 96.25 A | 100.75 A | 81.88 B | 80.50 B | 111.38 C |
| 11-VII | 112.00 AB | 105.25 B | 86.88 C | 87.25 C | 113.50 A |
| 18-VII | 101.75 A | 96.00 A | 84.50 B | 83.50 B | 98.50 A |
| 25-VII | 101.50 A | 99.00 A | 89.25 B | 86.50 B | 113.75 C |
| 30-VII | 99.25 AB | 96.50 B | 85.50 C | 88.75 C | 103.00 A |
| 07-VIII | 98.00 AB | 97.25 B | 80.75 C | 84.00 C | 103.00 A |
| 13-VIII | 90.00 A | 89.25 A | 80.50 B | 83.50 C | 89.00 A |
| 20-VIII | 101.00 A | 99.50 A | 84.25 B | 86.75 B | 103.25 A |

[a] Mean ($\bar{x}$) soil temperature values within same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

habitats monitored, excepting significant differences with the improved plots after 4 July (Table IV).

The average weekly high and low soil surface temperatures recorded during 1986 are shown in Tables V and VI. The weekly temperature values are derived from the average of seven day high and low temperature recorded values. Statistical analysis for significant differences between habitat types were not done due to non-replicated recordings. Comparison of soil surface temperatures recorded for the improved range, native range, and woodlot habitats, indicate consistently higher temperatures within the native range plots from 20 April - 10 July (Table V). The improved native range plots were consistently hotter than the native range plots during mid- to late-May, and hotter than the woodlot plots throughout the season (Table V). High temperatures in the improved habitat ranged from 64.4$^{\circ}$F in late April, to 120.0$^{\circ}$F on 31 July, 1986. The soil surface temperature range of the improved plots was considerably more extreme than that of the native plots which ranged from 75.9 - 117.9$^{\circ}$F.

Table VI depicts the weekly average high and low soil temperatures recorded for the ecotone and glade habitat types. The glade habitat was considerably hotter than all other habitats monitored (Tables V and VI). The ecotone habitat was cooler than all habitats throughout the season except the woodlot plots which were slightly cooler. The

TABLE V

WEEKLY AVERAGE HIGH AND LOW SOIL SURFACE TEMPERATURE[a] OCCURRING IN AN IMPROVED AND NATIVE RANGE, AND A WOODLOT HABITAT TYPE OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986

| | Habitat Type[b] | | | | | |
|---|---|---|---|---|---|---|
| | IMPRO | | NATIV | | WOODS | |
| Date[c] | High | Low | High | Low | High | Low |
| 13-IV | 79.71 | 49.00 | 79.00 | 54.57 | - | - |
| 20-IV | 64.43 | 42.29 | 75.86 | 47.86 | - | - |
| 27-IV | 71.43 | 42.43 | 89.14 | 51.28 | - | - |
| 07-V | 70.29 | 48.71 | 81.00 | 56.14 | 69.43 | 58.71 |
| 14-V | 76.14 | 56.57 | 87.86 | 64.29 | 73.43 | 63.57 |
| 22-V | 79.43 | 56.29 | 90.57 | 63.86 | 72.43 | 62.57 |
| 28-V | 74.13 | 54.25 | 87.00 | 61.25 | 66.75 | 59.88 |
| 05-VI | 84.00 | 57.33 | 104.33 | 62.83 | 71.17 | 62.17 |
| 12-VI | 84.00 | 65.29 | 95.00 | 66.86 | 72.71 | 67.43 |
| 18-VI | 89.29 | 65.57 | 101.57 | 72.14 | 75.29 | 67.00 |
| 25-VI | 94.57 | 65.57 | 105.57 | 70.57 | 76.71 | 67.86 |
| 03-VII | 100.14 | 68.57 | 106.57 | 74.57 | 79.14 | 68.57 |
| 10-VII | 101.86 | 71.57 | 105.86 | 75.86 | 80.00 | 72.57 |
| 17-VII | 110.29 | 74.86 | 106.86 | 76.29 | 81.14 | 73.86 |
| 23-VII | 114.71 | 73.43 | 112.14 | 75.29 | 83.00 | 72.81 |
| 31-VII | 120.00 | 76.29 | 118.14 | 78.14 | 94.57 | 75.86 |
| 07-VIII | 117.71 | 79.14 | 117.86 | 81.71 | 105.14 | 79.43 |
| 14-VIII | 96.71 | 69.71 | 102.57 | 73.71 | 87.57 | 70.43 |
| 21-VIII | 93.71 | 67.14 | 106.43 | 73.43 | 83.14 | 69.29 |
| 30-VIII | 98.14 | 71.14 | 111.14 | 77.44 | 90.29 | 71.86 |
| 06-IX | 96.43 | 65.23 | 103.43 | 70.71 | 92.57 | 67.43 |
| 13-IX | 81.43 | 65.86 | 89.29 | 72.29 | 75.29 | 67.29 |

[a] Weekly average of seven day temperature ($^{o}F$) recordings, non-replicated.

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat

TABLE V (Continued)

[c] Date indicates end of recording period for data represented for that date.

TABLE VI

WEEKLY AVERAGE HIGH AND LOW SOIL SURFACE TEMPERATURE[a] OCCURRING IN AN ECOTONE AND A GLADE HABITAT TYPE OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986

| | Habitat Type[b] | | | |
|---|---|---|---|---|
| | ECOTO | | GLADE | |
| Date[c] | High | Low | High | Low |
| 13-IV | 74.14 | 53.43 | - | - |
| 20-IV | 74.14 | 45.29 | - | - |
| 27-IV | 81.86 | 47.86 | - | - |
| 07-V | 75.57 | 53.71 | 101.43 | 52.43 |
| 14-V | 84.29 | 60.00 | 115.71 | 61.71 |
| 22-V | 79.14 | 60.00 | 111.43 | 59.14 |
| 28-V | 70.63 | 56.13 | 105.88 | 54.63 |
| 05-VI | 74.33 | 58.50 | 115.33 | 58.17 |
| 12-VI | 72.43 | 64.14 | 112.14 | 65.29 |
| 18-VI | 74.57 | 64.14 | 120.00 | 64.86 |
| 25-VI | 79.00 | 64.86 | 116.57 | 64.29 |
| 03-VII | 81.29 | 65.57 | 119.43 | 66.00 |
| 10-VII | 82.00 | 67.71 | 118.00 | 68.86 |
| 17-VII | 84.00 | 66.43 | 116.29 | 69.57 |
| 23-VII | 88.43 | 64.71 | 102.86 | 60.14 |
| 31-VII | 104.14 | 72.29 | 96.04 | 57.43 |
| 07-VIII | 116.43 | 80.57 | - | - |
| 14-VIII | 91.86 | 72.71 | - | - |
| 21-VIII | 82.57 | 71.00 | - | - |
| 30-VIII | 83.00 | 72.29 | - | - |
| 06-IX | 80.14 | 70.29 | - | - |
| 13-IX | 73.14 | 67.00 | - | - |

[a] Weekly average of seven day temperature ($^{o}F$) recordings, non-replicated.

[b] ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Date indicates end of recording period for data.

high soil surface temperatures for the ecotone habitat ranged from 70.63 - 116.43$^{o}$F, while low temperatures ranged from 45.29 - 80.57$^{o}$F. The range of high and low soil surface temperatures ranged from 96.04 - 119.43$^{o}$F, and from 52.43 - 69.57$^{o}$F, respectively (Table VI).

When evaluating the obvious trends and patterns associated with soil surface temperatures in each of the various habitat types during both years of study, they are very similar in all cases. The improved and native range plots are never significantly ($P \leq 0.05$) different throughout 1985, and are consistently similar in 1986 (Tables V and VI). The woodlot and ecotone habitats were always cooler than the improved plots during both years, and the glade provided the hottest micro-environmental conditions during both years (Tables V and VI). There were no significant differences between the improved and glade habitat soil surface temperatures during late season observations in 1985 (Table VI).

Soil Moisture. The gravimetric determination of soil moisture content in each of the various habitat types was critical in evaluating the effects of modification on the microenvironmental conditions within specific habitats. The mean ($\bar{x}$) percentage soil moisture content occurring in the different habitats are shown in Tables VII and VIII.

TABLE VII

MEAN ($\bar{X}$) PERCENTAGE SOIL MOISTURE CONTENT OCCURRING IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 12-VI | 15.69 A | 16.67 A | 18.08 A | 20.40 AB | 24.16 B |
| 19-VI | 17.88 AB | 15.00 A | 15.55 AB | 17.79 AB | 20 34 B |
| 27-VI | 13.78 A | 13.14 A | 15.49 A | 15.83 A | 16.48 A |
| 04-VII | 7.11 A | 7.59 A | 9.45 A | 10.16 A | 9.12 A |
| 11-VII | 3.42 A | 3.83 A | 5.45 AB | 6.74 B | 6.45 B |
| 18-VII | 9.49 A | 8.65 A | 8.87 A | 7.21 A | 18.05 B |
| 25-VII | 2.76 A | 3.68 A | 4.25 A | 4.86 A | 8.99 B |
| 30-VII | 8.04 A | 9.51 A | 7.95 A | 8.40 A | 15.64 B |
| 07-VIII | 16.11 A | 14.79 AB | 12.75 B | 14.53 AB | 22.19 C |
| 13-VIII | 5.61 A | 8.64 A | 6.19 A | 7.69 A | 13.23 B |
| 20-VIII | 5.37 A | 8.64 B | 4.56 A | 5.35 A | 12.76 C |

[a] Mean ($\bar{x}$) soil moisture values within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

TABLE VIII

MEAN ($\bar{X}$) PERCENTAGE SOIL MOISTURE CONTENT OCCURRING IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 27-III | 10.37 A | 17.14 B | 18.29 B | 19.56 B | 24.64 C |
| 13-IV | 12.92 A | 16.89 AB | 18.40 B | 20.71 B | 20.37 B |
| 08-V | 10.61 A | 14.86 B | 16.18 B | 17.19 B | 21.15 C |
| 04-VI | 12.94 A | 16.66 AB | 16.69 AB | 18.84 B | 24.62 C |
| 11-VI | 14.65 C | 18.39 AB | 17.40 AB | 19.27 B | 24.24 C |
| 17-VI | 12.66 A | 15.46 AB | 15.83 AB | 18.84 BC | 20.53 C |
| 25-VI | 9.72 A | 14.01 AB | 13.58 A | 18.72 B | 18.74 B |
| 03-VII | 7.46 A | 12.33 AB | 12.68 AB | 15 95 B | 14.22 B |
| 10-VII | 4.18 A | 8.09 AB | 7.35 AB | 9.95 B | 8.68 B |
| 16-VII | 2.15 A | 5.08 AB | 6.46 B | 8.46 B | 6.07 AB |
| 22-VII | 2.01 A | 3.26 AB | 5.71 C | 5.84 C | 5.23 BC |
| 29-VII | 1.26 A | 3.70 AB | 5.01 B | 3.71 AB | 5.98 B |
| 06-VIII | 7.11 AB | 6.64 A | 7.07 AB | 8.36 AB | 9.12 B |
| 12-VIII | 9.89 A | 14.55 B | 15.31 B | 15.89 B | 21.19 C |
| 21-VIII | 9.93 A | 14.95 B | 13.97 B | 15.66 B | 21.59 C |
| 30-VIII | 2.88 A | 7.94 B | 6.60 B | 12.28 C | 17.04 D |
| 06-IX | 9.25 A | 15.05 B | 13.24 B | 15.14 B | 21.13 C |

[a] Mean ($\bar{x}$) soil moisture values within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

The soil moisture content determined from 1985 data is shown in Table VII. When tested for significant ($P \leq 0.05$) differences between habitat types (Duncan 1955), there appeared to be virtually no differences realized by improvement of native range habitat. The improved range plots were only significantly ($P \leq 0.05$) drier than the native range plots during the week of 20 August, significantly ($P \leq 0.05$) drier than the woodlot habitat on 7 August, and significantly ($P \leq 0.05$) drier than the ecotone during the week of 11 July (Table VII). However, the improved plots were consistently drier than the glade plots except during the two week period of 27 June until 11 July (Table VII).

Although statistically significant drier soil moisture values were not shown for the improved plots at the 95% confidence level, it was the driest habitat tested throughout most of the observation periods and was actually an extremely dry habitat from July through August (Table VII).

Evaluation of soil moisture mean ($\bar{x}$) values for 1986 presents a similar, but expanded characterization of habitatal differences (Table VIII). Early season, 27 March - 8 May, mean ($\bar{x}$) moisture contents indicate the improved habitats to be significantly ($P \leq 0.05$) drier than all other habitats, excepting the native habitat for the week of 13 April (Table VIII). However, the period from 4 June until the week of 16 July showed no differences in soil moisture content between the improved range, native range, and the woodlot habitats. During the same period the improved habitat was significantly ($P \leq 0.05$) drier than the ecotone and glade plots. Throughout the end of the observation periods, following 6 August, the improved habitat was significantly drier than all other habitat types (Table VIII).

The improved habitat type exhibited soil moisture content values ranging from a high of 14.62 percent, to a minimum of 1.26 percent during the last week of July, 1986. The native range plots were consistently wetter than the improved plots throughout the 1986 season, with a high of 18.39 percent and a low of 3.26 percent soil moisture.

## Non-Parasitic Tick Abundance

### Trapping for Ticks

The use of carbon dioxide-baited sticky traps for comparison of lone star tick occurrence in differing habitat types provided information on the preferred habitat of indigenous populations. Data reported in the following tables are presented as the weekly mean ($\overline{x}$) numbers of ticks captured per trap. For the reader to gain an idea of the large number of lone star ticks actually represented, reference is made to a previously published work by Koch and

McNew (1982). From their results it is indicated that the capture of one adult lone star tick per one hour of Dry Ice® sampling was equivalent to 2,285 adult ticks per hectare.

1985. The mean ($\bar{x}$) number of female lone star ticks trapped in the various habitat types are shown in Table IX. There were no significant ($P \leq 0.05$) differences in the number of females captured among the improved, native, ecotone, and glade habitats. The woodlot habitat did, however, support significantly ($P \leq 0.05$) larger indigenous tick populations as revealed by trap captures during 22 and 29 May, 11 through 25 June, and 20 August (Table IX). Comparison of the number of ticks trapped in the woodlot and ecotone habitats revealed no significant ($P \leq 0.05$) differences except during the week of 11 June.

As would be expected, evaluation of the mean ($\bar{x}$) number of male lone star ticks trapped in the different habitat types revealed similar results to those of female tick capture (Table X). Trapping in the woodlot habitat captured significantly ($P \leq 0.05$) more ticks than any other habitat during the period from 22 May through 25 June, and on 23 July. There were no statistically significant ($P \leq 0.05$) differences in trap capture rates between the improved and native range, ecotone, and glade habitats at any time during the 1985 observation periods (Table X).

TABLE IX

MEAN ($\overline{X}$) NUMBER OF FEMALE LONE STAR TICKS TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 15-V[c] | 0.1 A | 0.2 A | 6.4 A | 0.5 A | 0.2 A |
| 22-V | 0.1 A | 0.4 AB | 0.9 B | 0.5 AB | 0.6 AB |
| 29-V | 0 A | 0.2 A | 1.0 B | 0.5 AB | 0 A |
| 05-VI | 0.2 A | 0.8 A | 1.6 A | 0.5 A | 0.4 A |
| 11-VI | 0.2 A | 0.2 A | 3.4 B | 0.5 A | 0.3 A |
| 18-VI | 0 A | 0.3 AB | 0.9 B | 0.6 AB | 0.2 A |
| 25-VI | 0 A | 0.4 AB | 1.1 B | 0.7 AB | 0.4 AB |
| 02-VII | 0.1 A | 0.3 A | 0.2 A | 0.2 A | 0.2 A |
| 09-VII | 0.1 A | 0.1 A | 0.4 A | 0 A | 0.1 A |
| 17-VII[c] | 0 A | 0.1 A | 1.1 A | 0.6 A | 0 A |
| 23-VII | 0 A | 0 A | 0.4 A | 0.1 A | 0 A |
| 31-VII | 0 | 0 | 0 | 0 | 0 |
| 06-VIII | 0 A | 0.1 A | 0 A | 0 A | 0.1 A |
| 13-VIII | 0 A | 0 A | 0.4 A | 0 A | 0 A |
| 20-VIII | 0 A | 0 A | 0.2 B | 0 A | 0 A |

[a] Mean ($\overline{X}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

TABLE X

MEAN ($\bar{X}$) NUMBER OF MALE LONE STAR TICKS TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 15-V[c] | 0 A | 0.3 A | 7.3 A | 0.9 A | 0.5 A |
| 22-V | 0.1 A | 0.1 A | 1.1 B | 0.2 A | 0.4 AB |
| 29-V | 0 A | 0 A | 0.6 B | 0.1 A | 0.1 A |
| 05-VI | 0.2 A | 0.4 A | 1.2 B | 0.5 A | 0.2 A |
| 11-VI | 0.2 A | 0.1 A | 1.9 B | 1.1 AB | 0.3 A |
| 18-VI | 0 A | 0.1 A | 0.7 B | 0.3 AB | 0.4 AB |
| 25-VI | 0.1 A | 0.3 AB | 0.8 B | 0.7 AB | 0.3 AB |
| 02-VII | 0.2 A | 0.1 A | 0.1 A | 0.1 A | 0.1 A |
| 09-VII | 0 A | 0.2 A | 0.2 A | 0.1 A | 0.1 A |
| 17-VII[c] | 0 A | 0.1 A | 0.6 A | 0.5 A | 0 A |
| 23-VII | 0 A | 0 A | 0.2 B | 0 A | 0.1 A |
| 31-VII | 0 | 0 | 0 | 0 | 0 |
| 06-VIII | 0 | 0 | 0 | 0 | 0 |
| 13-VIII | 0 | 0 | 0 | 0 | 0 |
| 20-VIII | 0 | 0 | 0 | 0 | 0 |

[a] Mean ($\bar{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

Although statistically significant differences at the 95% confidence level were not evident in most comparisons of trap captures of adults between habitat types (Tables IX and X), calculation of the mean ($\bar{x}$) ticks per hectare in each of the habitats reveals very interesting results as to the actual number of lone star ticks in an area. The most female ticks recovered in the improved plots were on 5 and 11 June with approximately 457 per hectare. The native range plot trap recoveries were also the highest on 5 June, with 1,828 ticks per hectare. The largest number of female ticks recovered in the woodlot habitat occurred 15 May, with over 14,620 per hectare recorded. The greatest female capture rates in the ecotone and glade habitats were 1,599 per hectare on 25 June, and 1,371 per hectare on 22 May, respectively. Calculation of the number of male ticks occurring per hectare in 1985 were similar to those for female ticks. There were over 16,680 male ticks per hectare in the woodlots, compared to a maximum of only 457 per hectare in the improved plots.

The mean ($\bar{x}$) number of nymphal lone star ticks recovered per trap in the different habitat types is shown in Table XI. Significantly ($P \leq 0.05$) greater numbers of nymphs were captured in the woodlot plots than in any of the other habitats during most of the early and mid-season (May through the first week of July) trapping periods. There were no statisically significant ($P \leq 0.05$) differences shown for

TABLE XI

MEAN ($\bar{X}$) NUMBER OF LONE STAR TICK NYMPHS TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 15-V[c] | 0.7 A | 0.5 A | 55.9 B | 3.7 A | 0.6 A |
| 22-V | 0.7 A | 3.4 AB | 8.1 B | 1.0 A | 0.6 A |
| 29-V | 0.2 A | 0.4 A | 1.9 B | 0.8 A | 0.2 A |
| 05-VI | 0.3 A | 0.7 A | 8.4 B | 2.2 A | 0.8 A |
| 11-VI | 0.2 A | 1.1 A | 12.3 A | 12.9 A | 0.9 A |
| 18-VI | 0.7 A | 1.6 A | 10.3 B | 4.2 AB | 0.4 A |
| 25-VI | 0.2 A | 2.1 A | 11.8 B | 1.9 A | 1.0 A |
| 02-VII | 0.1 A | 0.7 A | 3.4 B | 0.5 A | 1.0 AB |
| 09-VII | 0.1 A | 2.4 A | 4.2 A | 1.0 A | 0.9 A |
| 17-VII[c] | 0 A | 0 A | 10.8 B | 1.6 A | 0.9 A |
| 23-VII | 0 A | 0 A | 3.3 A | 0.4 A | 4.6 A |
| 31-VII | 0 A | 0.5 A | 5.3 A | 0.3 A | 0 A |
| 06-VIII | 0 A | 0.3 A | 1.4 A | 2.4 A | 0 A |
| 13-VIII | 0.1 A | 0.8 AB | 2.4 B | 1.3 AB | 0.1 A |
| 20-VIII | 0.1 A | 0 A | 3.4 B | 1.5 AB | 0.2 A |

[a] Mean ($\bar{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

trap recovery of nymphs when comparing the improved range, native range, ecotone, and glade habitats (Table XI).

Observations of the mean ($\bar{x}$) number of larvae per carbon dioxide-baited trap for the improved and native range, and the ecotone habitats showed no significant ($P \leq 0.05$) differences. Significant differences at the 95% confidence level between the improved range and woodlot habitats were realized on 13 and 20 August, and in the ecotone on 17 and 31 July (Table XII).

1986. Comparison of the mean ($\bar{x}$) number of female lone star ticks trapped from each of the various habitat types is shown in Table XIII. There were no significant ($P \leq 0.05$) differences in female tick captures in the improved and native range plots, and the glade plots. The woodlot habitat did have significantly ($P \leq 0.05$) larger numbers of females captured when compared to the improved plots during observations on 22 and 27 March, 5, 12, 20, and 26 April, and on 20 May (Table XIII). The occurrence of female ticks within the improved habitat plots was not observed until 7 May, and none were recorded after 2 July (Table XIII). Ticks were trapped in all other habitats as early as 22 March in the native range, woodlot, and ecotone plots and 5 April in the glade. Peak female activity occurred in the woodlot, ecotone and glade habitats during mid- to late April (Table XIII).

TABLE XII

MEAN ($\overline{X}$) NUMBER OF LONE STAR TICK LARVAE TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 02-VII | 0 A | 0 A | 0 A | 0.1 A | 0 A |
| 09-VII | 0 A | 0 A | 0.3 A | 0.3 A | 0 A |
| 17-VII[c] | 0 A | 0 A | 0 A | 19.4 B | 0 A |
| 23-VII | 0 A | 0 A | 0.3 A | 0 A | 12.2 B |
| 31-VII | 0 A | 0 A | 3.0 A | 30.2 B | 0 A |
| 06-VIII | 0 A | 5.7 A | 2.9 A | 18.3 A | 21.6 A |
| 13-VIII | 0 A | 0 A | 37.3 B | 15.7 AB | 0 A |
| 20-VIII | 0 A | 0 A | 24.3 B | 9.2 AB | 0 A |

[a] Mean ($\overline{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

TABLE XIII

MEAN ($\overline{X}$) NUMBER OF FEMALE LONE STAR TICKS TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 22-III | 0 A | 0.4 AB | 1.8 C | 0.9 B | 0 A |
| 27-III | 0 A | 0.2 A | 0.9 B | 0.6 AB | 0 A |
| 05-IV | 0 A | 0.1 A | 1.2 B | 0.4 A | 0.2 A |
| 12-IV | 0 A | 0.2 AB | 0.9 AB | 1.1 B | 0.6 A |
| 20-IV[c] | 0 A | 0 A | 1.6 B | 0.3 AB | 0.3 AB |
| 26-IV | 0 A | 0 A | 3.0 B | 1.4 C | 0 A |
| 07-V | 0.1 A | 0.1 A | 1.4 B | 1.1 AB | 0.2 A |
| 13-V | 0 A | 0.1 A | 0.3 A | 0.8 A | 0.2 A |
| 20-V | 0 A | 0 A | 1.4 B | 0.3 A | 0.1 A |
| 27-V | 0.1 A | 0.2 A | 0.5 A | 0.2 A | 0.2 A |
| 04-VI | 0.2 A | 0.3 A | 0.3 A | 0.7 A | 0.2 A |
| 10-VI | 0 A | 0.2 AB | 0.4 AB | 0.7 B | 0.3 AB |
| 17-VI | 0.1 A | 0.1 A | 0.3 A | 0.1 A | 0 A |
| 24-VI | 0.1 A | 0.7 A | 0.1 A | 0.4 A | 0.2 A |
| 02-VII | 0.1 A | 0.1 A | 0 A | 0.1 A | 0.1 A |
| 08-VII | 0 A | 0 A | 0.1 A | 0.1 A | 0 A |
| 15-VII | 0 A | 0 A | 0 A | 0.1 A | 0.1 A |
| 22-VII | 0 A | 0.1 A | 0.1 A | 0.1 A | 0.1 A |
| 29-VII | 0 | 0 | 0 | 0 | 0 |
| 06-VIII | 0 A | 0 A | 0.1 B | 0 A | 0 A |
| 13-VIII | 0 A | 0 A | 0 A | 0 A | 0.1 A |
| 20-VIII | 0 A | 0 A | 0.1 A | 0.1 A | 0 A |
| 30-VIII | 0 | 0 | 0 | 0 | 0 |
| 06-IX | 0 A | 0 A | 0.1 A | 0 A | 0 A |

[a] Mean ($\overline{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat

TABLE XIII (Continued)

WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

The maximum numbers of female ticks captured in the various habitats in 1986 were similar to those reported for 1985. The improved plot trap captures did not exceed 457 female ticks per hectare, while the native range, woodlot, ecotone, and glade habitats had 914, 6,855, 2,513, and 1,371 per hectare, respectively.

Results of trapping for male lone star ticks in the different habitat types indicated no significant ($P \leq 0.05$) differences in mean ($\bar{x}$) tick numbers between the improved and native range, and glade plots(Table XIV). The woodlot and ecotone habitats did have significantly greater tick trap captures during early season observations made on 22 and 27 March (Table XIV). The woodlot plots had significantly ($P \leq 0.05$) greater numbers of males than the improved native range habitat on 5 and 12 April, 7 and 20 May, and 8 July (Table XIV). Trapping in the improved habitats did not reveal any male ticks except on 4 June, while all other habitats showed tick occurrence during March.

Carbon dioxide nymphal trapping exhibited very few significant ($P \leq 0.05$) differences in the capture of ticks in the various habitat types (Table XV). The woodlot habitat had significantly ($P \leq 0.05$) more nymphs than the improved plots on 22 March, 7 May, 10 June, 8 July, and on 20 and 30 August (Table XV).

TABLE XIV

MEAN ($\overline{X}$) NUMBER OF MALE LONE STAR TICKS TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[a]

| | Habitat Type [b] | | | | |
|---|---|---|---|---|---|
| Date | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 22-III | 0 A | 0.6 AB | 1.6 C | 1.0 BC | 0 A |
| 27-III | 0 A | 0.2 A | 0.8 B | 0.8 B | 0.2 A |
| 05-IV | 0 A | 0.4 AB | 0.7 B | 0.6 AB | 0.1 AB |
| 12-IV | 0 A | 0.2 AB | 1.5 BC | 2.3 C | 0.3 AB |
| 20-IV[c] | 0 A | 0.1 A | 0.7 A | 0 A | 0.4 A |
| 26-IV | 0 A | 0.1 A | 2.0 A | 1.5 A | 0 A |
| 07-V | 0 A | 0.1 A | 1.7 B | 0.9 AB | 0.4 A |
| 13-V | 0 A | 0.1 A | 0.3 A | 0.8 A | 0.2 A |
| 20-V | 0 A | 0.1 A | 0.4 B | 0.2 A | 0 A |
| 27-V | 0 A | 0.1 A | 0.3 A | 0.2 A | 0.2 A |
| 04-VI | 0.1 A | 0.2 A | 0.2 A | 0.2 A | 0.2 A |
| 10-VI | 0 A | 0.2 A | 0.5 A | 0.7 A | 0.2 A |
| 17-VI | 0 A | 0.1 A | 0.2 A | 0.2 A | 0.1 A |
| 24-VI | 0 A | 0.6 A | 0.2 A | 0.2 A | 0.1 A |
| 02-VII | 0 A | 0 A | 0.1 A | 0 A | 0.1 A |
| 08-VII | 0 A | 0 A | 0.3 B | 0 A | 0 A |
| 15-VII | 0 A | 0 A | 0 A | 0.2 A | 0.1 A |
| 22-VII | 0 A | 0 A | 0.1 A | 0 A | 0 A |
| 29-VII | 0 | 0 | 0 | 0 | 0 |
| 06-VIII | 0 | 0 | 0 | 0 | 0 |
| 13-VIII | 0 A | 0 A | 0.1 A | 0.1 A | 0 A |
| 20-VIII | 0 A | 0 A | 0.1 A | 0 A | 0 A |
| 30-VIII | 0 | 0 | 0 | 0 | 0 |
| 06-IX | 0 A | 0 A | 0.1 A | 0.1 A | 0.1 A |

[a] Mean ($\overline{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat

TABLE XIV (Continued)

WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

TABLE XV

MEAN ($\overline{X}$) NUMBER OF LONE STAR TICK NYMPHS TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[a]

| Date | Habitat Type[b] | | | | |
|---|---|---|---|---|---|
| | IMPRO | NATIV | WOODS | ECOTO | GLADE |
| 22-III | 0 A | 0.6 AB | 1.1 B | 0.3 A | 0 A |
| 27-III | 0 A | 0.1 A | 2.1 AB | 2.6 B | 0.5 A |
| 05-IV | 0.1 A | 1.0 A | 5.1 A | 1.0 A | 0.6 A |
| 12-IV | 0 A | 0.5 A | 3.4 A | 21.6 A | 1.0 A |
| 20-IV[c] | 0 A | 0.3 A | 2.3 A | 0.7 A | 1.4 A |
| 26-IV | 0 A | 0.1 A | 12.0 A | 7.6 A | 1.0 A |
| 07-V | 0 A | 0.6 A | 9.9 B | 8.1 B | 0.3 A |
| 13-V | 0 A | 0 A | 0.3 A | 3.2 A | 0.3 A |
| 20-V | 0 A | 4.6 A | 4.7 A | 0.9 A | 0.2 A |
| 27-V | 0 A | 0.2 A | 1.1 A | 3.7 A | 1.3 A |
| 04-VI | 0.1 A | 0.2 A | 2.5 A | 5.7 A | 11.1 A |
| 10-VI | 0 A | 0 A | 2.8 B | 2.1 AB | 2.4 AB |
| 17-VI | 0 A | 0.1 A | 8.5 A | 1.0 A | 0.4 A |
| 24-VI | 0.1 A | 6.8 A | 1.2 A | 5.2 A | 2.8 A |
| 02-VII | 0 A | 0.1 A | 0.5 A | 2.3 A | 0.2 A |
| 08-VII | 0 A | 0 A | 0.8 B | 0.7 AB | 0.1 A |
| 15-VII | 0 A | 0.1 A | 0.2 A | 0.5 A | 7.7 A |
| 22-VII | 0 A | 0.3 A | 1.6 A | 0 A | 0 A |
| 29-VII | 0 A | 0 A | 0.2 A | 0 A | 0 A |
| 06-VIII | 0 A | 0 A | 1.8 A | 0.4 A | 0.1 A |
| 13-VIII | 0 A | 0 A | 4.7 A | 5.7 A | 0.9 A |
| 20-VIII | 0 A | 1.5 AB | 5.1 B | 1.6 AB | 2.6 AB |
| 30-VIII | 0 A | 0 A | 1.8 B | 0.8 AB | 0.9 AB |
| 06-IX | 0 A | 0.1 A | 2.3 A | 6.3 A | 0.2 A |

[a] Mean ($\overline{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat

TABLE XV (Continued)

WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

[c] Dates with superscript denotes analysis for significant differences based on two replications (ALPHA=0.05, DF=4).

The mean ($\bar{x}$) number of larval lone star ticks captured on traps in the various habitats are shown in Table XVI. No significant ($P \leq 0.05$) differences in the numbers trapped were seen between any of the habitats tested except the ecotone plots. The ecotone plots provided significantly ($P \leq 0.05$) greater numbers of larvae when compared to the improved plots on 29 July and 20 August (Table XVI). Although accurate actual number estimates cannot be calculated for larval recoveries due to their aggregated distributions, observed numbers per trap differ greatly between the habitat types.

Although statistically significant ($P \leq 0.05$) differences in tick trap captures between habitat types were not broadly evident for any lifestage during either 1985 or 1986, the actual numbers of ticks occurring in the various habitats was largely different. The woodlot and ecotone habitats had consistently the largest numbers of ticks captured, followed by the glade and native range plots. The improved native range plots were consistently the most free of non-parasitic ticks, all lifestages considered, throughout both years of study. It should also be noted that a comparison of trap captures for the improved habitat during 1985 and 1986 shows a reduced population of indigenous ticks in 1986. This is possibly due to the reduced suitability of the habitat over a two year period. In other words, observations in 1985 on the improved plots

TABLE XVI

MEAN ($\overline{X}$) NUMBER OF LONE STAR TICK LARVAE TRAPPED IN DIFFERENT HABITAT TYPES OF THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[a]

| Date | Habitat Type[b] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | IMPRO | | NATIV | | WOODS | | ECOTO | | GLADE | |
| 24-VI | 0 | A | 0 | A | 0 | A | 0 | A | 0.1 | A |
| 02-VII | 0 | | 0 | | 0 | | 0 | | 0 | |
| 08-VII | 0 | | 0 | | 0 | | 0 | | 0 | |
| 15-VII | 0 | | 0 | | 0 | | 0 | | 0 | |
| 22-VII | 0 | A | 1.3 | A | 1.3 | A | 1.3 | A | 0 | A |
| 29-VII | 0 | A | 0 | A | 0 | A | 5.2 | B | 0 | A |
| 06-VIII | 0 | A | 0 | A | 9.0 | A | 1.4 | A | 0.8 | A |
| 13-VIII | 0 | A | 0 | A | 0.4 | A | 4.2 | A | 0 | A |
| 20-VIII | 0 | A | 0 | A | 3.5 | AB | 12.8 | B | 0 | A |
| 30-VIII | 0.1 | A | 0 | A | 15.2 | A | 1.6 | A | 0 | A |
| 06-IX | 0 | A | 0 | A | 4.3 | A | 6.8 | A | 0 | A |

[a] Mean ($\overline{x}$) tick numbers within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=12).

[b] IMPRO = Improved native range habitat
NATIV = Native range habitat
WOODS = Woodlot habitat
ECOTO = Ecotone habitat
GLADE = Glade habitat

were picking-up populations carried-over from the pre-existing native range habitat. These populations were decreased as time progressed and therefore reduced numbers were captured in 1986 observations.

### Flagging for Larval Ticks

Very little informative data was collected by flagging for larvae in the various habitat types. There were no larvae collected by flagging in the improved or glade habitats at any time. This technique was most effective in the woodlot plots, mean ($\bar{x}$) larvae per sample ranged from 330.88 to 10.25 on 21 and 30 August, 1986, respectively. The ecotone habitat was the next largest supportive habitat type for larval recovery with 14.75 and 8.50 larvae per sample recorded on 14 and 21 August, respectively.

Mean ($\bar{x}$) values for larvae per sample were highly variable due to the clustering or extremely aggregated distributions occurring in the field. Standard deviation (SD) values for each mean ($\bar{x}$) value calculated was at least 25 percent greater than the mean ($\bar{x}$) value.

## Tick Survival and Fecundity in Different Habitats

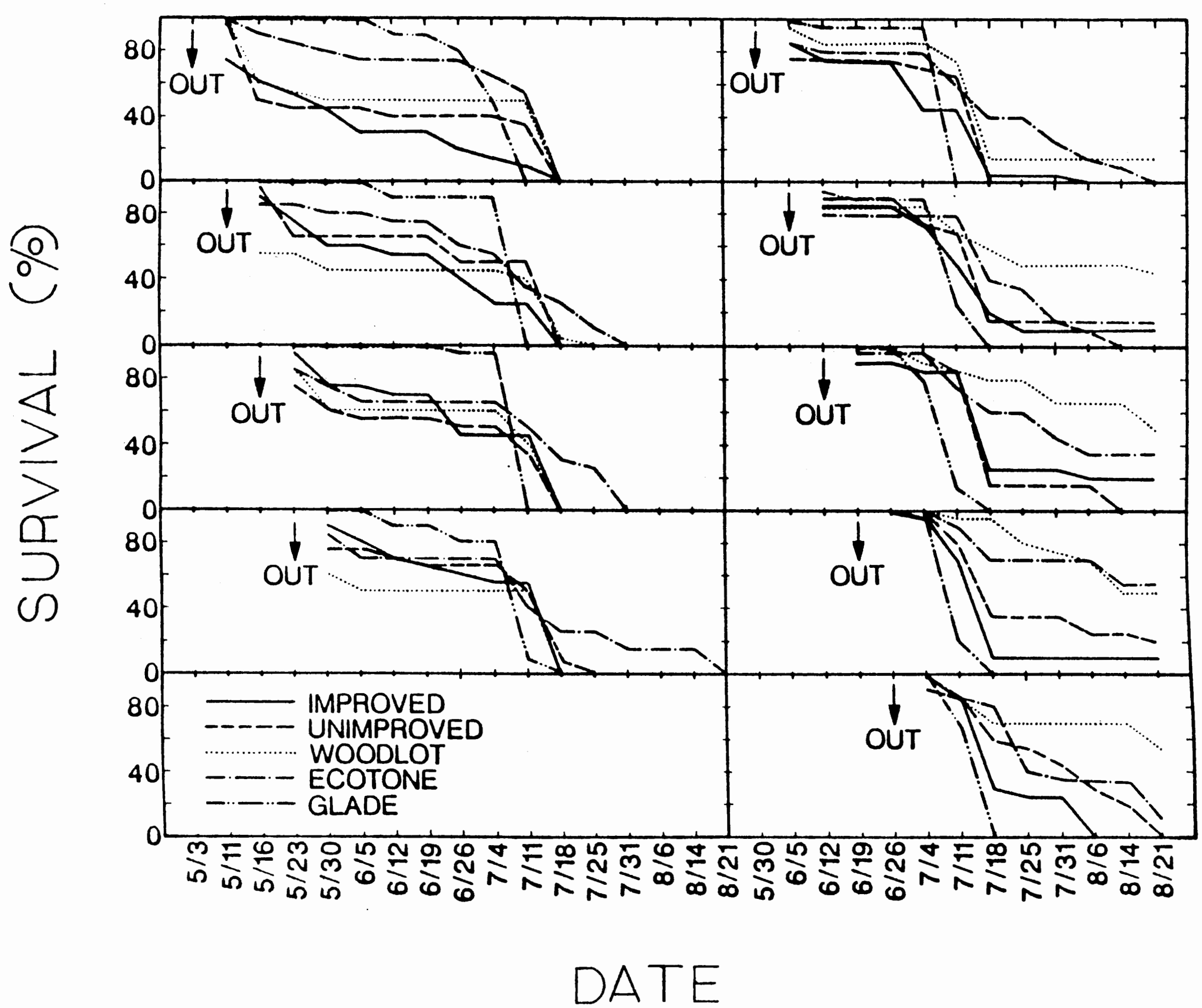
The suitability of a habitat to support lone star tick populations is dependent on its' ability to provide adequate edaphic conditions for survival, successful oviposition and incubation of eggs, and availability of hosts. The exposure of various lifestages of lone star ticks to the various habitat types provided evidence for determination of the suitability of the different habitats.

Unengorged Female Tick Survival

1985. Observations of the survival of unfed female ticks exposed to the various habitat types is illustrated in Figure 12. The Improved and native range plots were very similar in their effects on tick survival in all observation periods. The time period of 4 July through 18 July appeared to be critical in the survival of ticks in all habitat types and for all exposure dates. Ticks released early in the season (May) survived for 10-13 weeks in the ecotone which was the most suitable habitat. Early season (3 May - 30 May) releases in the woodlot habitat survived only moderately but later season (5 June - 26 June) exposures exhibited the greatest survival potentials. Late season (June) tick exposures in the woodlot and ecotone habitats survived until 21 August, after which they likely became inactive and entered diapause.

1986. Observations of the survival potential of ticks exposed to the five different habitat types were combined with observations of the ascension behavior of the ticks in the exposure cages. The height at which the ticks were

Figure 12. Survival Relationships of Unfed Female Lone Star Ticks Exposed to Various Habitat Types, CHWMA, Oklahoma, 1986


SURVIVAL (%)
DATE
OUT
IMPROVED
UNIMPROVED
WOODLOT
ECOTONE
GLADE
0
40
80
5/3
5/11
5/16
5/23
5/30
6/5
6/12
6/19
6/26
7/4
7/11
7/18
7/25
7/31
8/6
8/14
8/21

observed upon initiation of observations was indexed as; 0-1 was equivalent to 0 up to 15.25 cm, 1-2 equalled 15.26 to 30.5 cm, and 2-3 was equivalent to 30.51 up to 45 cm above the soil surface. The mean ($\bar{x}$) percent survival and the mean ($\bar{x}$) ascension index values for lone star ticks exposed to the various habitat types are shown in Table XVII.

Early season (22 March - 6 April) exposures were similar in the percent and length of tick survival among the different habitat types (Table XVII). Progression of the season indicated greater survival in the woodlot and ecotone habitats, and an increase in the ascension height of the ticks in all habitats. The improved and native range plots were similar in observations of tick survival, neither habitat supporting ticks for longer than 12 weeks (Table XVII). The ecotone and woodlot habitats had ticks that survived for longer than 16 weeks from early season exposures, and longer than 12 weeks in late season exposures. These results are similar to those reported by Robertson and others (1975), in which cleared, open habitats were significantly less supportive of exposed lone star ticks.

The increasing ascension heights as the season progressed was obvious in all habitat types, and possibly reflects the increased host seeking activity as Fall approached.

TABLE XVII

MEAN ($\overline{X}$) PERCENT SURVIVAL[a] AND ASCENSION ACTIVITY OF UNFED FEMALE LONE STAR TICKS EXPOSED TO VARIOUS HABITAT TYPES OF THE CHWMA, OKLAHOMA, 1986

| | | Habitat Type[b] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rel | | IMPR | | NATI | | WOOD | | ECOT | | GLAD | |
| Date[c] | WPR[d] | %A[e] | HI[f] | %A | HI | %A | HI | %A | HI | %A | HI |
| | 2 | 45 | 2.4 | 30 | 2.4 | 50 | 1.0 | 45 | 2.4 | 40 | 2.6 |
| | 4 | 45 | 2.4 | 30 | 3.0 | 50 | 2.2 | 45 | 2.4 | 40 | 2.4 |
| 1 | 8 | 25 | 2.2 | 25 | 2.2 | 50 | 2.2 | 30 | 2.7 | 20 | 3.0 |
| | 12 | 0 | -[g] | 0 | - | 35 | 3.0 | 30 | 2.7 | 0 | - |
| | 16 | - | - | - | - | - | - | 10 | 2.0 | - | - |
| | 2 | 85 | 1.9 | 80 | 1.8 | 95 | 1.6 | 95 | 1.6 | 95 | 1.8 |
| | 4 | 55 | 2.5 | 90 | 2.7 | 85 | 2.0 | 85 | 2.4 | 65 | 2.3 |
| 2 | 8 | 25 | 2.4 | 90 | 3.0 | 60 | 2.6 | 70 | 2.9 | 55 | 3.0 |
| | 12 | 0 | - | 20 | 3.0 | 15 | 1.8 | 25 | 2.6 | 25 | 2.8 |
| | 16 | - | - | 0 | - | 0 | - | 0 | - | 0 | - |
| | 2 | 80 | 2.3 | 85 | 1.9 | 95 | 2.7 | 95 | 2.0 | 95 | 2.4 |
| | 4 | 40 | 3.0 | 85 | 2.2 | 85 | 2.2 | 95 | 2.8 | 90 | 2.6 |
| 3 | 8 | 25 | 3.0 | 65 | 2.8 | 65 | 3.0 | 70 | 2.9 | 55 | 3.0 |
| | 12 | 0 | - | 0 | - | 0 | - | 20 | 2.0 | 0 | - |
| | 16 | - | - | - | - | - | - | 5 | 1.0 | - | - |
| | 2 | 85 | 2.4 | 75 | 2.5 | 70 | 2.7 | 95 | 2.7 | 95 | 3.0 |
| | 4 | 70 | 2.9 | 75 | 3.0 | 60 | 2.8 | 85 | 2.8 | 85 | 3.0 |
| 4 | 8 | 10 | 3.0 | 35 | 2.7 | 30 | 3.0 | 45 | 2.7 | 45 | 2.6 |
| | 12 | 0 | - | 0 | - | 0 | - | 5 | 1.0 | 0 | - |
| | 16 | - | - | - | - | - | - | 0 | - | - | - |
| | 2 | 100 | 2.8 | 95 | 2.6 | 80 | 1.9 | 90 | 2.8 | 95 | 2.6 |
| | 4 | 90 | 2.0 | 90 | 2.2 | 55 | 2.8 | 80 | 2.7 | 90 | 2.9 |
| 5 | 8 | 10 | 3.0 | 25 | 2.8 | 5 | 2.0 | 75 | 2.7 | 25 | 3.0 |
| | 12 | 0 | - | 0 | - | 0 | - | 15 | 0.3 | 0 | - |
| | 16 | - | - | - | - | - | - | 0 | - | - | - |
| | 2 | 100 | 3.0 | 90 | 2.9 | 75 | 2.8 | 95 | 3.0 | 100 | 3.0 |
| 6 | 4 | 60 | 2.7 | 75 | 2.9 | 60 | 2.8 | 85 | 2.8 | 75 | 3.0 |
| | 8 | 0 | - | 25 | 2.8 | 5 | 3.0 | 25 | 3.0 | 45 | 3.0 |
| | 12 | - | - | 0 | - | 0 | - | 0 | - | 0 | - |
| | 2 | 80 | 2.6 | 95 | 3.0 | 95 | 2.8 | 100 | 3.0 | 95 | 3.0 |
| 7 | 4 | 55 | 3.0 | 90 | 3.0 | 70 | 2.9 | 75 | 3.0 | 90 | 2.9 |

TABLE XVII (Continued)

| Rel Date | WPR | IMPR %A | IMPR HI | NATI %A | NATI HI | WOOD %A | WOOD HI | ECOT %A | ECOT HI | GLAD %A | GLAD HI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 0 | - | 0 | - | 10 | 3.0 | 25 | 3.0 | 0 | - |
| | 12 | - | - | - | - | 0 | - | 10 | 0 | - | - |
| | 2 | 90 | 2.8 | 100 | 2.9 | 95 | 2.9 | 100 | 3.0 | 100 | 3.0 |
| 8 | 4 | 70 | 3.0 | 80 | 2.7 | 65 | 2.8 | 90 | 2.9 | 90 | 2.9 |
| | 8 | 0 | - | 10 | 3.0 | 5 | 3.0 | 25 | 3.0 | 20 | 1.0 |
| | 12 | - | - | 0 | - | 5 | 3.0 | 5 | 0 | 0 | - |
| | 2 | 94 | 3.0 | 100 | 3.0 | 73 | 2.4 | 100 | 2.9 | 100 | 3.0 |
| 9 | 4 | 30 | 2.0 | 67 | 2.9 | 20 | 2.3 | 94 | 3.0 | 80 | 3.0 |
| | 8 | 13 | 3.0 | 0 | - | 0 | - | 40 | 1.7 | 0 | - |
| | 12 | 0 | - | - | - | - | - | 0 | - | - | - |
| | 2 | 60 | 2.6 | 70 | 2.4 | 20 | 1.0 | 40 | 1.3 | 60 | 2.4 |
| 10 | 4 | 0 | - | 5 | 3.0 | 20 | 1.0 | 40 | 1.0 | 0 | - |
| | 8 | - | - | 0 | - | 0 | - | 0 | - | - | - |

[a] Survival or mortality of ticks determined by recording as dead if no response was seen following 10 breathes on cage

[b] Habitat types;
IMPR = Improved native range habitat type
NATI = Native range habitat type
WOOD = Woodlot habitat type
ECOT = Ecotone habitat type
GLAD = Glade habitat type

[c] Dates ticks were exposed to the various habitat types; 1 = 22 March, 2 = 29 March, 3 = 06 April, 4 = 13 April, 5 = 20 April, 6 = 27 April, 7 = 07 May, 8 = 14 May, 9 = 22 May, 10 = 05 June

[d] Number of weeks post-exposure of ticks to habitat

[e] Percent alive at date post-exposure

[f] Height Index value (0 - 3.0); 0 = floor of cage, 1 = 15.25 cm, 2 = 30.50 cm, 3 = 45 cm

[g] No observation recorded, indicated by ( - )

### Fecundity of Engorged Female Ticks

The fecundity of engorged female lone star ticks exposed to the various habitat types was determined by their degree of success in ovipositing and by the viability of the eggs they produced.

1985. The mean ($\bar{x}$) observed oviposition success and estimated percentage eclosion of those eggs oviposited is shown in Table XVIII. Oviposition success in the improved habitat plots was reduced in comparison to the woodlot and ecotone plots, but was somewhat greater than that of the native range plots. However, the percentage egg hatch of the egg masses in the improved plots was the least of any habitat with only one of the three observed arenas exhibiting any egg hatch. It is obvious from the pre-oviposition period values that seasonal influence contributes to the biological fecundity progressions (Table XVIII).

Observations of the pre-hatch period indicate a longer time period was required for larval eclosion in the native plots in comparison to the other plots (Table XVIII). It is also interesting to note the increasing trend of oviposition success in the woodlot and ecotone habitats. This is likely due to more favorable edaphic moisture conditions in these habitats, mold growth was observed on engorged females exposed in these habitats in mid-May.

TABLE XVIII

MEAN ($\overline{X}$) OBSERVED OVIPOSITION SUCCESS AND EGG HATCHABILITY OF ENGORGED LONE STAR TICKS EXPOSED TO DIFFERENT HABITAT TYPES OF THE CHWMA, OKLAHOMA, 1985

| Habitat Type | Release Date | Oviposition % success | Oviposition Pre-ovip[a] | Egg Hatch % hatch[b] | Egg Hatch Pre-hatch[c] |
|---|---|---|---|---|---|
| Improved | 05 May | 66 | 3 | 0 | - |
| | 16 May | 66 | 2 | < 25 | 6 |
| | 03 June | 33 | 2 | 0 | - |
| Native | 05 May | 25 | 3 | 25-50 | 8 |
| | 16 May | 17 | 2 | < 25 | 8 |
| | 03 June | 8 | 2 | > 75 | 4 |
| Woodlot | 05 May | 92 | 3 | > 75 | 3 |
| | 16 May | 75 | 2 | 25-50 | 4 |
| | 03 June | 100 | 2 | 25-50 | 4 |
| Ecotone | 05 May | 75 | 3 | > 75 | 4 |
| | 16 May | 75 | 2 | > 75 | 4 |
| | 03 June | 100 | 2 | 50-75 | 3 |
| Glade | 05 May | 25 | 4 | > 75 | 4 |
| | 16 May | 58 | 2 | 25-50 | 5 |
| | 03 June | 8 | 2 | 0 | - |

[a] Pre-oviposition period (wk) following exposure of the engorged ticks to the various habitat types

[b] Estimated percent egg mass hatch

[c] Period (wk) following oviposition before egg hatch was observed

1986. Oviposition and egg hatch success of engorged female lone star ticks exposed to the various habitat types is shown in Table XIX. Females exposed to the improved habitat plots exhibited a reduced mean ($\bar{x}$) percent oviposition success and egg hatch when compared to the other habitat types. The glade habitat fecundity observations are very similar to those of the improved range, exhibiting extremely reduced oviposition success for ticks exposed 22 May and reduced egg hatch throughout the season (Table XIX).

A more accurate means of estimating percentage egg hatch was used in 1986. Egg masses were collected randomly from each habitat type at specified periods following the initiation of hatch, and laboratory analysis of the number of eggs per egg mass performed (Table XX). The influence of the habitat type on the percent eclosion of eggs appeared to be on the rate of eclosion more than on the success of eclosion. This is indicated by the increasing percent values for the native range, woodlot, ecotone, and glade plots in contrast to the decreasing values for observations of the improved habitat type (Table XX).

Fecundity observations in 1985 and 1986 indicate similar habitat traits which provide insight into their suitability for lone star ticks. The improved and native range habitats both appeared to be somewhat less favorable for tick propagation during late season exposures (Tables XVIII and XIX). The ecotone and especially the woodlot

TABLE XIX

MEAN ($\overline{X}$) OBSERVED OVIPOSITION SUCCESS AND EGG HATCHABILITY OF ENGORGED LONE STAR TICKS EXPOSED TO DIFFERENT HABITAT TYPES OF THE CHWMA, OKLAHOMA, 1986

| Habitat | Release | Oviposition | | Egg Hatch | |
|---|---|---|---|---|---|
| Type | Date | % success | Pre-ovip[a] | % hatch[b] | Pre-hatch[c] |
| Improved | 06 April | 100 | 3 | < 25 | 10 |
| | 27 April | 75 | 2 | 25-50 | 7 |
| | 22 May | 58 | 2 | 0 | - |
| | 12 June | 100 | 2 | < 25 | 4 |
| Native | 06 April | 100 | 3 | > 75 | 10 |
| | 27 April | 100 | 2 | > 75 | 8 |
| | 22 May | 100 | 2 | > 75 | 5 |
| | 12 June | 83 | 2 | 25-50 | 5 |
| Woodlot | 06 April | 100 | 3 | > 75 | 11 |
| | 27 April | 100 | 2 | > 75 | 8 |
| | 22 May | 100 | 2 | < 25 | 5 |
| | 12 June | 100 | 2 | > 75 | 6 |
| Ecotone | 06 April | 100 | 3 | > 75 | 12 |
| | 27 April | 100 | 3 | > 75 | 9 |
| | 22 May | 78 | 2 | < 25 | 5 |
| | 12 June | 83 | 2 | 50-75 | 5 |
| Glade | 06 April | 85 | 3 | > 75 | 10 |
| | 27 April | 92 | 2 | > 75 | 7 |
| | 22 May | 45 | 2 | 25-50 | 6 |
| | 12 June | 100 | 2 | 0 | - |

[a] Pre-oviposition period (wk) following exposure of the engorged ticks to the various habitat types

[b] Estimated percent egg mass hatch

[c] Period (wk) following oviposition before egg hatch was observed

TABLE XX

MEAN ($\overline{X}$) PERCENT EGG MASS ECLOSION OF EGGS OVIPOSITED BY FEMALE LONE STAR TICKS EXPOSED TO DIFFERING HABITAT TYPES OF THE CHWMA, OKLAHOMA, 1986

| Habitat Type | Weeks Post-hatch initiation | | |
|---|---|---|---|
| | 2 | 3 | 4 |
| Improved | 85.19($\pm$8.15) | 64.81($\pm$43.62) | 82.02($\pm$3.34) |
| Native | 77.95($\pm$6.44) | 88.34($\pm$8.29) | 90.56($\pm$9.17) |
| Woodlot | 65.86($\pm$7.08) | 78.08($\pm$8.45) | 95.73($\pm$2.22) |
| Ecotone | 44.31($\pm$12.49) | 83.88($\pm$11.06) | 93.96($\pm$4.27) |
| Glade | 40.70($\pm$24.00) | 54.18($\pm$24.04) | 60.36($\pm$20.65) |

[a] Values in parentheses indicate standard deviation (SD) of mean ($\overline{X}$)

habitats were considerably more conducive to lone star tick fecundity during observations of all exposure periods, with oviposition of never less than 75% and greater than 25 percent estimated egg hatch during most observations.

## Visitation and Utilization of Native and Improved Range Habitats

Determination of the frequency of visitation and the extent to which white-tailed deer utilized the improved native range habitat, in comparison to the native range areas, was made based on three different observation techniques. These techniques consisted of counting the number of deer pellet groups occurring along a transect of each plot, gravimetrically and/or physically determining forage utilization from forage clipping samples, and the use of an infrared beam transect to monitor deer presence within a known area.

### Deer Pellet Group Counts

1985. The mean ($\bar{x}$) number of white-tailed deer pellet groups observed in 1985 on both the improved and native range plots are shown in Table XXI. Significantly ($P \leq 0.05$) greater numbers of pellet groups were observed on the improved range plots throughout July, 1985. An increased number of pellet groups within an area was assumed to indicate an increased usage or time period spent in that

TABLE XXI

MEAN ($\bar{X}$) NUMBER OF DEER PELLET GROUPS OBSERVED ON BELT TRANSECTS OF IMPROVED AND NATIVE RANGE HABITAT PLOTS, CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1985[a,b]

| Date | Habitat Type | |
|---|---|---|
| | Improved | Native |
| 20-VI | 2.25 A (112.46) | 1.50 A (74.97) |
| 04-VII | 0.25 A (12.49) | 0 B |
| 11-VII | 7.25 A (362.36) | 1.00 B (49.98) |
| 24-VII | 10.25 A (512.29) | 1.75 B (87.47) |
| 07-VIII | 3.25 A (162.44) | 1.50 A (74.97) |
| 22-VIII | 2.25 A (112.46) | 0.25 A (12.49) |

[a] Mean ($\bar{x}$) values within the same date, followed by the same letter are not significantly different (ALPHA=0.05,DF=3).

[b] Values in parentheses indicate number of pellet groups/ha (transect area=0.02 ha).

area. The number of pellet groups did not significantly differ during early-season (20 June) or during mid- to late season counts (7 and 22 July, Table XXI). The period observed to have the greatest number of deer pellet groups recorded for both habitat types was during late-June, with 512.30 pellet groups per hectare on the improved range plots and 87.47 pellet groups per hectare on the native range sites (Table XXI).

1986. Observations of the number of deer pellet groups occurring on the improved and native range plots in 1986 were not significantly ($P \leq 0.05$) different prior to 3 July (Table XXII). The improved range habitat had significantly ($P \leq 0.05$) more pellet groups than the native range on 3, 23, and 30 July and on 19 August (Table XXII). For all observation periods, excluding 10 June, the improved range habitat had at least two-fold the number of pellet groups per hectare as the native range habitat. However, statistically significant differences at the $P \leq 0.05$ level were not obtained due to variance among samples within each habitat type. When reevaluating the analysis of the the data it was noted that statistically significant differences between habitat types did exist at the $P \leq 0.10$ level for the entire period from 16 July until 19 August.

The period showing the heaviest visitation of the improved plots, as indicated by the number of pellet groups

TABLE XXII

MEAN ($\bar{X}$) NUMBER OF DEER PELLET GROUPS OBSERVED ON BELT TRANSECTS OF IMPROVED AND NATIVE RANGE HABITAT PLOTS, CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[a,b]

| Date | Habitat Type | |
|---|---|---|
| | Improved | Native |
| 05-VI | 2.50 A (124.95) | 0.75 A (37.49) |
| 10-VI | 1.50 A (74.97) | 1.50 A (74.97) |
| 17-VI | 3.75 A (187.43) | 0.25 A (12.49) |
| 24-VI | 3.50 A (174.93) | 1.25 A (62.48) |
| 03-VII | 3.00 A (149.94) | 1.00 B (49.98) |
| 10-VII | 1.75 A (87.47) | 0.50 A (24.99) |
| 16-VII | 1.00 A (49.98) | 0 A |
| 23-VII | 7.75 A (387.35) | 0.50 B (24.99) |
| 30-VII | 2.25 A (112.46) | 0 B |
| 07-VIII | 2.50 A (124.95) | 0.50 A (24.99) |
| 12-VIII | 1.75 A (87.47) | 0 A |
| 19-VIII | 3.00 A (149.94) | 0.50 B (24.99) |
| 30-VIII | 3.75 A (187.43) | 0.50 A (24.99) |
| 06-IX | 1.75 A (87.47) | 0.50 A (24.99) |

[a] Mean ($\bar{x}$) values within the same date, followed by the same letter are not significantly different (ALPHA=0.05,DF=3).

[b] Values in parentheses indicate number of pellet groups/ha (transect area=0.02 ha).

per hectare, was 23 July with greater than 387 pellet groups per hectare. The peak observance of pellet groups on the native range plots occurred earlier in the season with 74.97 groups per hectare recorded on 10 June (Table XXII).

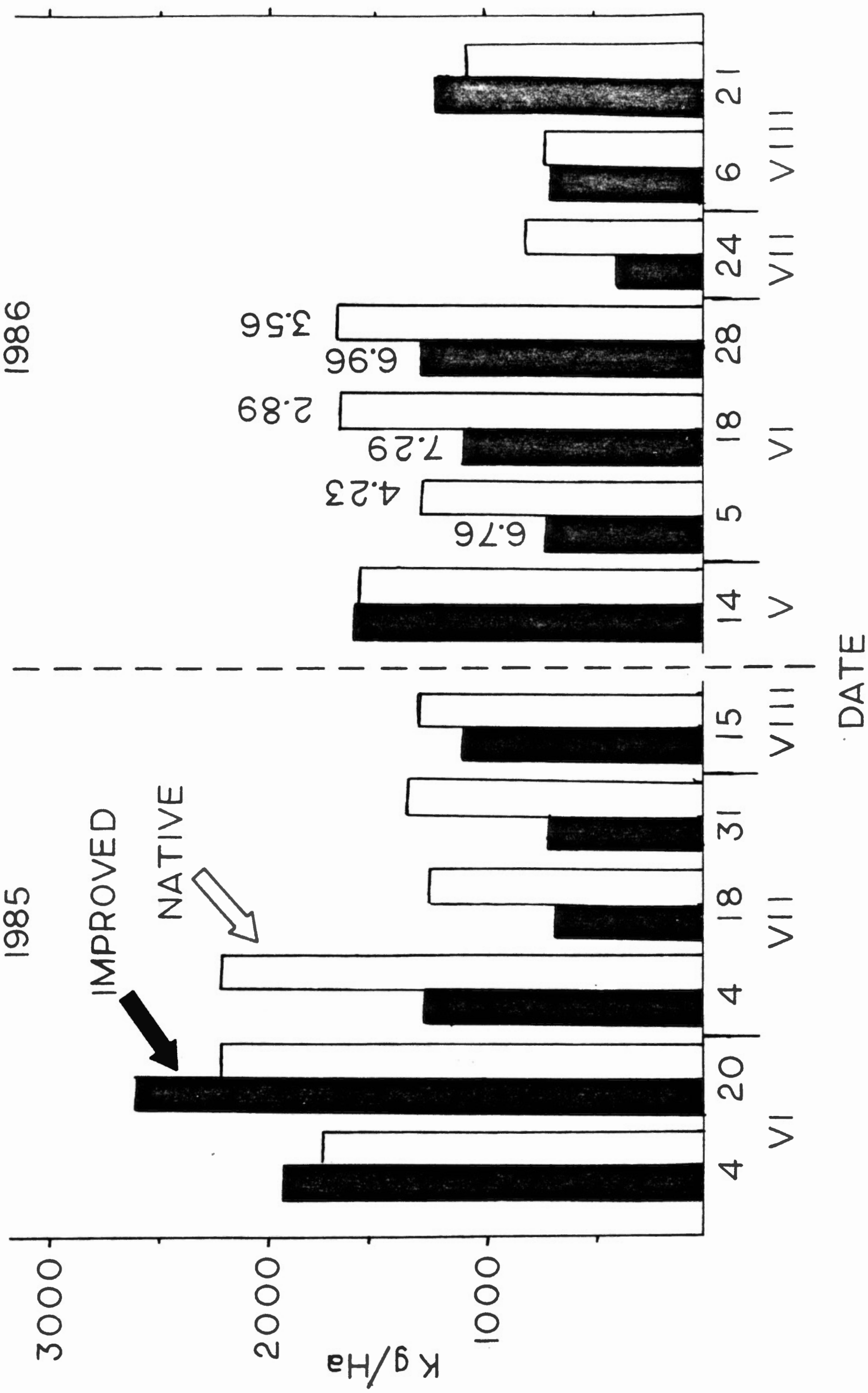
## Apparent Forage Utilization

Estimates of the amount of and degree to which white-tailed deer utilized the available forage within the improved and native range plots were essential in determining the value of habitat improvement. Seasonal utilization trends are also important in evaluating the potential benefits of range improvement.

A comparative bar-chart of the dry matter forage production estimates for 1985 and 1986 is provided in Figure 13. The improved range plots produced heavier dry-matter forage yeilds in early season observations, 4 and 20 June, 1985 and 14 May, 1986. Forage production was consistently greater in the native range plots from 4 July through 15 August, 1985 and from 5 June through 6 August, 1986.

Although forage yields were greater in the native range plots throughout most of the season during both years, comparison of samples of the digestible protein content showed impressive results (Figure 13). The percentage digestible protein content for the improved range plots was significantly ($P \leq 0.05$) higher than that of the native range plots for all samples analyzed. From these data the

Figure 13. Dry Matter Forage Production Estimates for Improved and Native Range Habitats, 1985 and 1986, and Percentage Digestible Protein (%DP) Content For Three Observation Periods During 1986, CHWMA, Oklahoma


1985
1986
IMPROVED
NATIVE
K g/Ha
3000
2000
1000
6.76
4.23
7.29
2.89
6.96
3.56
4
VI
20
4
18
VII
31
15
VIII
14
V
5
18
VI
28
24
VII
6
21
VIII
DATE

improved forage component was definitively more nutritous and should have provided a more palatable diet for the deer.

1985. Observed estimates of forage utilization determined from the comparative physical measurements of the standing forage height occurring inside and outside wildlife exclosures are illustrated in Figure 14. Consistently greater differences in the forage heights, those taken inside and outside exclosures, is shown for the improved range when compared to the native range plots. This procedure was not sufficient in providing an accurate estimate of forage utilization and was abandoned for data collection in 1986.

1986. Early season observations in May and June indicated significantly ($P \leq 0.05$) greater preference and utilization of the improved plots compared to the native range habitat. Apparent forage consumption of the improved and native range plots is depicted in Figure 15. The percentage forage consumed was derived from the difference between total standing forage produced within exclosures and the standing forage produced in areas accessible to white-tailed deer. As was observed in deer pellet group count observations, a significant difference in utilization of the two habitats was realized within three weeks following early season forage harvest. Late season comparisons of consumption in August showed no statistically

Figure 14. Observed Estimate of Forage Utilization From the Improved and Native Range Habitats, Determined by Comparison of Forage Height Measurements Taken Inside and Outside Wildlife Exclusion Cages Within Each Plot, CHWMA, 1985

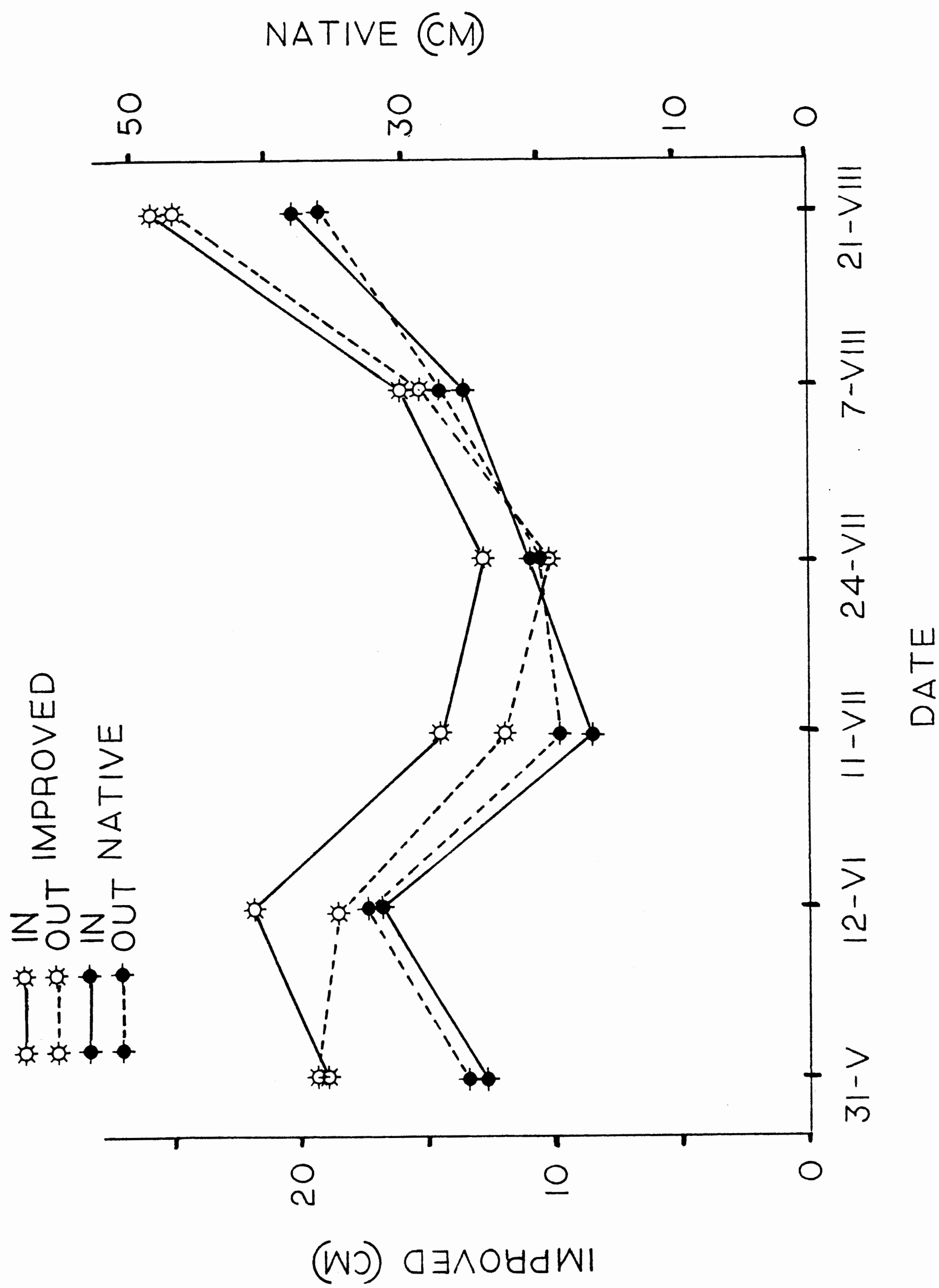
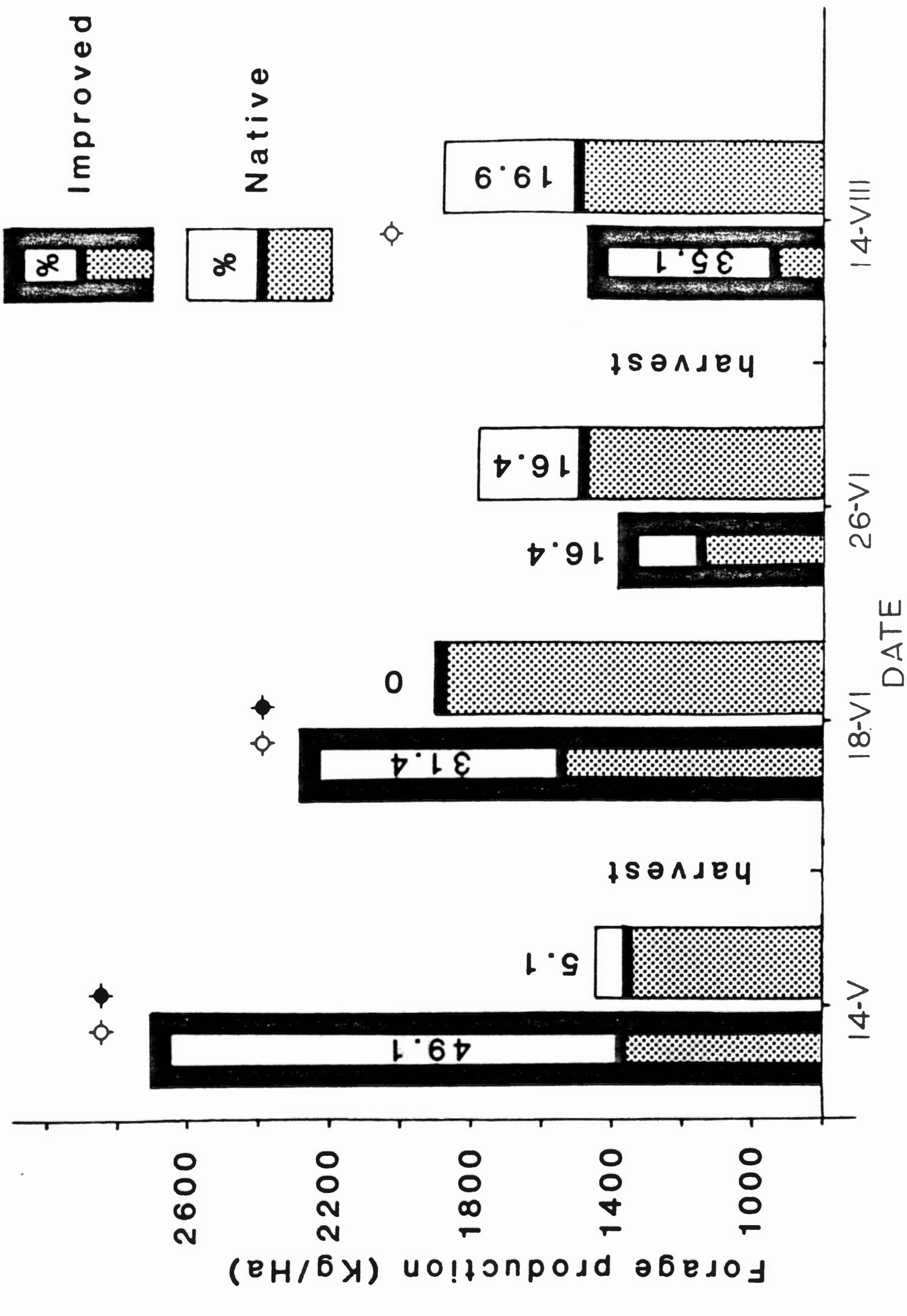

NATIVE (CM)
50
30
10
0
IMPROVED (CM)
20
10
0
31-V
12-VI
11-VII
24-VII
7-VIII
21-VIII
DATE
IN
OUT IMPROVED
IN
OUT NATIVE

Figure 15. Apparent Forage Consumption Comparisons of Improved and Native Range Habitats, CHWMA, Oklahoma, 1986: ◇ = Significant ($P \leq 0.05$) Differences in Forage Production Between Habitats; ◆ = Significant ($P \leq 0.05$) Differences in Utilization of Specific Habitats; Bars Represent Total Forage Production (Kg/ha) Within Exclosure, Stippled Regions Indicate Dry Matter Production (Kg/ha) Outside Exclosure, and Percentage Consumption Values Contained Within Bars



Forage production (Kg/Ha)
2600
2200
1800
1400
1000
DATE
14-V
18-VI
26-VI
14-VIII
harvest
harvest
49.1
5.1
31.4
0
16.4
16.4
35.1
19.9
%
Improved
%
Native

significant ($P \leq 0.05$) differences between habitat types. During this period the native range plots did, however, produce more forage than the improved plots. These utilization patterns of improved range corresponds with periods of peak tick host acquisition as reported by Patrick and Hair (1977). This finding is particularly important since it demonstrates the potential of manipulating tick-infested deer to utilize and spend greater amounts of time in areas unsuitable for tick propagation.

Infrared Transect Procedure

The mean ($\bar{x}$) number of white-tailed deer transgressions per deer day (the period from approximately 2000 until 0800 CST) of infrared beam transects of improved and native range sites are shown in Table XXIII. Statistically significant ($P \leq 0.05$) differences between the visitation of the two habitats was shown on 4 and 11 June, with 25.9 and 20.9 transgreesions of the improved plots and 10.9 and 6.2 transgressions of the native range plots, respectively.

Deer visitation of the improved plots was heaviest during mid-spring and early summer (April - May), peaking at approximately 40 transgressions per day on 14 May. This peak was likely attributable to tne period when the improved plot forage was in a lush growth stage. Measurable visitation was similar in the two study areas during the period from mid-June to late-August (Table XXIII).

TABLE XXIII

MEAN ($\overline{X}$) RECORDED DEER TRANSGRESSIONS/DEER DAY[a] OF INFRARED BEAM TRANSECTS ON IMPROVED AND NATIVE RANGE HABITATS IN THE CHWMA, ADAIR AND CHEROKEE COUNTIES, OKLAHOMA, 1986[b]

| Date | Habitat Type | |
|---|---|---|
| | Improved | Native |
| 28-III[c] | 12.40 | 5.80 |
| 06-IV[c] | 5.14 | 4.00 |
| 13-IV[c] | 24.86 | 2.14 |
| 20-IV[c] | 6.43 | 23.00 |
| 26-IV[c] | 0.83 | 1.50 |
| 14-V | 39.07 A | 20.11 A |
| 20-V[c] | 31.40 | 20.40 |
| 28-V | 29.70 A | 25.93 A |
| 04-VI | 25.90 A | 10.93 B |
| 11-VI | 20.90 A | 6.17 B |
| 18-VI | 16.50 A | 15.25 A |
| 25-VI | 9.07 A | 5.87 A |
| 02-VII | 19.73 A | 20.40 A |
| 09-VII | 11.13 A | 11.73 A |
| 16-VII | 11.73 A | 12.70 A |
| 23-VII | 7.27 A | 8.87 A |
| 30-VII | 10.60 A | 6.90 A |
| 06-VIII | 12.53 A | 8.10 A |
| 13-VIII | 15.53 A | 16.53 A |
| 20-VIII | 15.40 A | 14.03 A |
| 30-VIII[c] | 3.86 | 15.50 |

[a] Deer day = period from ca. 2000 - 0800 CST.

[b] Mean ($\overline{x}$) transgression values within the same date, followed by the same letter are not significantly different (ALPHA=0.05, DF=4).

[c] Non-replicated values (equipment absence or failure).

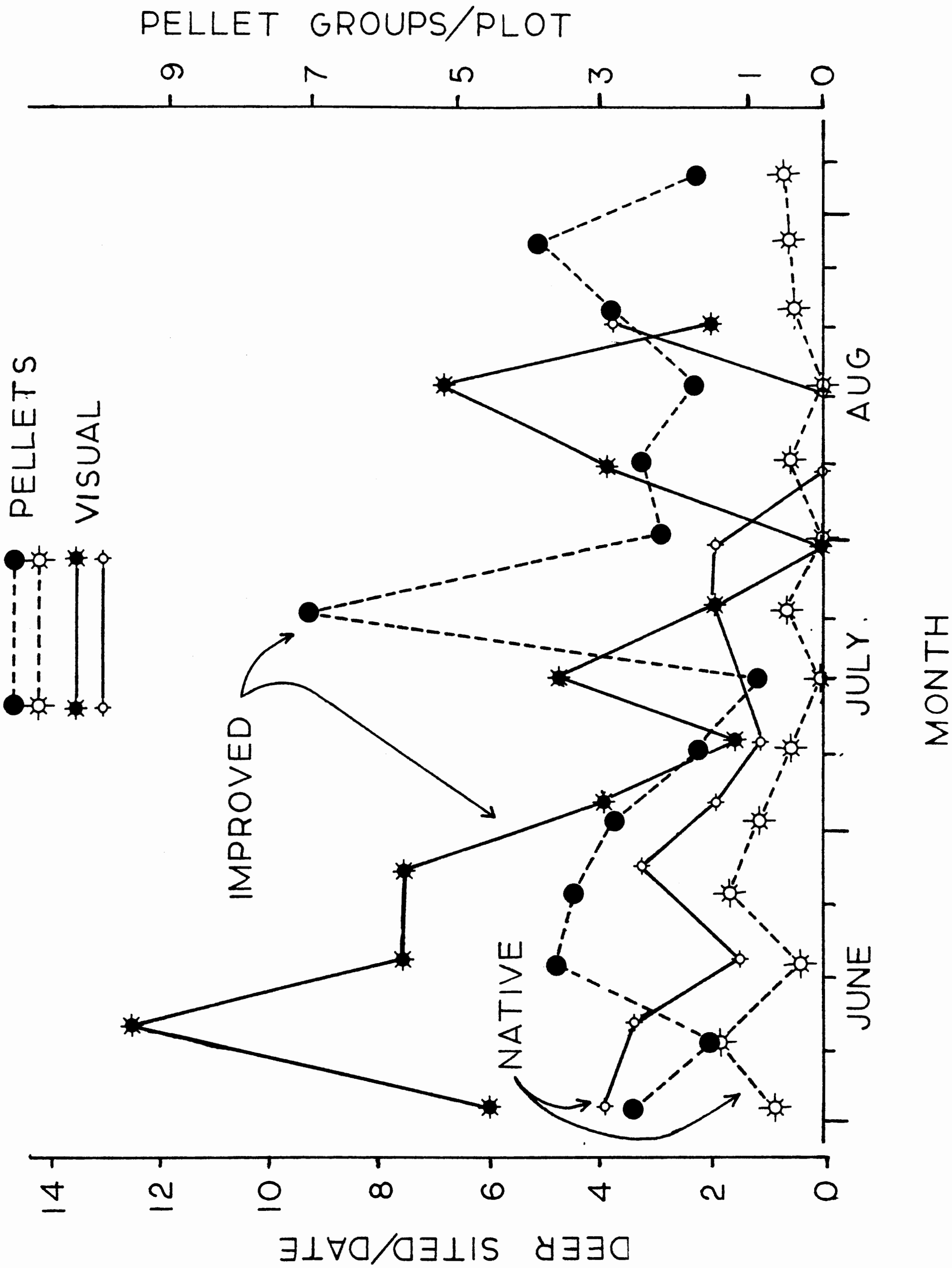
The potential of the infrared beam transect technique for monitoring white-tailed deer visitation of specific areas appeared to produce data which was indicative of deer usage. The use of this technique simultaneously with other techniques and the correlation of results would provide a useful means of measuring deer activity and frequency within specific areas. The need for a high degree of replication of each habitat type monitored by the infrared beam transect method is realized by the conservativeness of significance for mean ($\bar{x}$) values in Table XXIII.

## Visual Observations of Deer Behavior

Spotlight count observations of the occurrence of white-tailed deer in the various habitat types were tallied and averaged for the weekly period they were recorded. Early season counts in June revealed high numbers of deer viewed on all plot types. The improved plots had 8-13 deer spotted on them during the period from 10 - 25 June, while the native range and woodlot plots had up to four deer spotted on them during the same period. Observations recorded for the period from 8 July through 6 August showed greatly reduced numbers in all plots.

A comparison of the number of white-tailed deer sited and the mean ($\bar{x}$) number of pellet groups observed in the differing habitat types is shown in Figure 16. There are

Figure 16. Comparison of the Number of White-Tailed Deer Visually Observed and the Mean ($\bar{x}$) Number of Deer Pellet Groups Occurring in the Improved and Native Range Habitats, CHWMA, Oklahoma, 1986


PELLET GROUPS/PLOT
9
7
5
3
1
0
PELLETS
VISUAL
IMPROVED
NATIVE
JUNE
JULY
AUG
MONTH
DEER SITED/DATE
14
12
10
8
6
4
2
0

similar trends indicated in the peak periods of nighttime deer activity and pellet groups observed on the plots.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

The ability of five different habitat types to support the survival and reproductive requirements of the lone star tick, *Amblyomma americanum* (L.), were evaluated in the Cookson Hills region of northeastern Oklahoma, during the tick seasons of 1985 and 1986. Considering the effects of habitat conditions on the occurrence and abundance of lone star ticks in an area, an integration of forage improvement and wildlife management practices were implemented to evaluate their potential in controlling tick populations in an area-wide approach.

Comparison of the environmental conditions, both ambient and edaphic, occurring in the various habitat types showed few differences between the improved and native range areas. However, these areas had consistently lower percent relative humidities and soil moisture content, and higher ambient temperatures and soil surface temperatures in comparison to the other habitat types.

Soil moisture content comparisons among the various study sites were probably the most significant abiotic indicator of habitat suitability for lone star ticks. Statistical comparisons of mean ($\bar{x}$) soil moisture content of the different habitats monitored from mid-June until late August 1985, showed the improved and native range, woodlot, and ecotone habitat types to be insignificantly different. However, observations recorded for 1986 from late March through early September indicated the improved and native range plots were significantly different from the other habitat types from 27 March through 8 May, and from 22 June through early September, excluding the week of 6 August.

The native range habitat type has been shown to be less suitable as lone star tick habitat than other types such as woodlots, ecotone areas, and glades (Semtner et al., 1971a,b; Semtner and Hair, 1973b; Meyer et al., 1982). The results of evaluations of environmental parameters in this study indicated that the improvement of the native range by cultivation and forage component species did not improve its' suitability as tick habitat.

There appeared to be significant seasonal as well as habitat influence on the occurrence of the various lone star tick lifestages. The results of trapping adult ticks showed the improved and native range plots to be the least infested of all habitats studied throughout both years, particularly during observations recorded in March, April, and May of 1986. These periods coincide with peak adult tick activity in the woodlot and ecotone habitats. Nymphal and larval tick captures from the improved and native range plots were also significantly less than those recorded for the woodlot and ecotone habitats throughout the study periods of 1985 and 1986. There was also much greater recovery of nymphs in the woodlot plots in comparison to the ecotone habitat type. It should be noted that a comparison of trap captures in the improved native range plots for 1985 and 1986 showed even greater reductions of adults and nymphs during the second year of plot cultivation.

The exposure of unfed female lone star ticks to the various habitat types to evaluate their survival potential and activity patterns showed a reduced tick longevity in the improved and native range plots in comparison to the woodlot and ecotone areas. Tick exposures made in April and May, 1986, in the improved and native range plots were the shortest-lived of all habitats as well as other exposure periods. Engorged female ticks monitored for fecundity behavior in the different habitat types were affected by improved habitat edaphic conditions, similar to the results of unfed tick survival trials. There was a reduced oviposition success and larval eclosion observed in the improved and native range habitats during 1985 and 1986.

An increased utilization of the improved range in comparison to the native range plots was shown during both years. Early season data indicated significantly greater visitation and utilization of the improved plots, which was likely induced by an increased forage palatability in these areas. Digestible protein content was also significantly greater in the improved habitat when compared to the native range plots. By the manipulation or enticement of deer to spend more time in open habitat types an increased probability of tick deposition in these areas was achieved.

These results infer that habitat types such as native range and improved native range were less supportive of lone star tick populations, indicated by a reduced survival potential in these areas. White-tailed deer can be used to "transport" parasitic stages of lone star ticks into these areas from ecotone habitats which are more suitable for both deer and ticks. By spending more time in these areas and depositing replete ticks into these areas, the overall population of lone star ticks within a particular deer's range should be reduced.

Tick population reduction, or at least the formation of pasture areas of reduced tick suitability, should be an economic incentive for livestock producers, recreational area and wildlife managers to implement such integrated management practices. The potential economic benefits gained by controlling lone star tick numbers would make these practices feasible for the livestock producer (Ervin et al. 1987). In addition, the reduced threat of annoyance and possible disease transmission in tourism and wildlife management areas would add to the recreational economic development of lone star tick infested regions, particularly the Ozark region of northeastern Oklahoma.

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